

AD-A054 279

BATTELLE COLUMBUS LABS OHIO
EVALUATION OF PROTECTIVE COATINGS SYSTEMS FOR BUOYS.(U)
MAY 77 R J DICK, B J MERRELL, L J NOWACKI
BATT-PPC-45

F/G 11/3

DOT-CG-51331-A

USCG-D-24-77

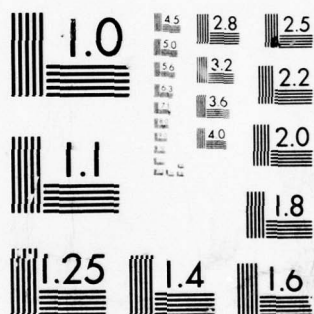
NL

UNCLASSIFIED

| OF |
AD
A054 279



END
DATE
FILMED
6-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REPORT NO. CG-D-24-77

12

AD A 054279

FOR FURTHER TRAN

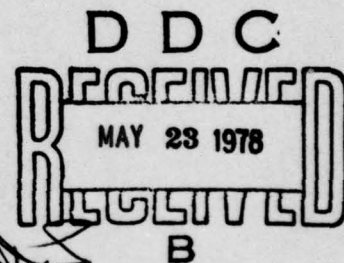
EVALUATION OF PROTECTIVE
COATINGS SYSTEMS FOR BUOYS

R. J. Dick, B. J. Merrell,
L. J. Nowacki, and J. R. Sherrard



May 31, 1977

FINAL REPORT



Document is available to the U. S. public through the
National Technical Information Service,
Springfield, Virginia 22161

AD No. _____
DDC FILE COPY

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

**UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20590**

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

The contents of this report do not necessarily reflect the official view or policy of the Coast Guard; and they do not constitute a standard, specification, or regulations.

This report, or portions thereof, may not be used for advertising, publications, or promotional purposes. Citation of trade names and manufacturers does not constitute endorsement or approval of such products.

W. L. King

W. L. KING
Captain, U. S. Coast Guard
Chief, Environmental and
Transportation Technology Division
Office of Research and Development
U. S. Coast Guard Headquarters
Washington, D. C. 20590

Technical Report Documentation Page

1. Report No. 18 USC-D-24-77	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle 6 Evaluation of Protective Coatings Systems for Buoys		5. Report Date VI May 77	6. Performing Organization Code BCL
7. Author(s) 301 R. J. Dick, B. J. Merrell, L. J. Nowacki J. R. Sherrard		8. Performing Organization Report No. BATT-PPC-45	
9. Performing Organization Name and Address Battelle Columbus Laboratories/ 505 King Avenue Columbus, Ohio 43201		10. Work Unit No. (TRAIS) 2515.01	
12. Sponsoring Agency Name and Address Department of Transportation United States Coast Guard Office of Research and Development Washington, D. C. 20590		11. Contract or Grant No. 757 DOT-CG-51331-A	
15. Supplementary Notes		13. Type of Report and Period Covered 9 Final Report 12 63 p.	
14. Sponsoring Agency Code G-DET-2			
16. Abstract <p>Thirty-one premium antifouling marine coatings systems have been examined to determine their extended service life potential for steel, aluminum, and plastic buoys. Complete systems of substrate, pretreatments, primers, anticorrosive midcoats, and antifouling topcoats containing various toxicants are included in the program. Eight of the 31 systems are carried over from a previous study (Report No. CG-D-74-75 of March 21, 1975) and have been examined after 77 months of static immersion in seawater near Daytona Beach, Florida. The performance of seven systems is noteworthy, particularly that of the Vinyl-High Rosin Type 121/63 and the elastomeric sheet with organotin toxicant. Performances of the Standard Vinyl Rosin Type 121 in the specification system and over self-cured and post cured zinc silicates with a high build vinyl are slightly poorer but are still rated excellent. The remaining systems are epoxy/epoxy-coal tar and a vinyl rosin containing an organotin fluoride toxicant.</p> <p>Twenty-three coatings systems in the present study have been exposed for 18 months. In addition, panels of each system have been damaged before and during exposure to simulate adverse deployment and service conditions. All systems were damaged by impact, gouge, and abrasion before immersion and others by impact and gouge after 6 and 12 months' immersion. No detrimental effects have been observed after the 18 months' immersion.</p> <p>Although performance ratings are difficult after these brief exposure times, the performances of 13 systems have been tentatively rated as "outstanding to excellent", 3 systems have been rated "fair", and 7 systems have been rated "unacceptable".</p>			
17. Key Words Marine Coatings Systems, Anti-fouling Coatings and Anticorrosive Coatings for Buoys, Marine Toxicants, Coatings Performance Under Simulated Deployment and Service Damaged Condition		18. Distribution Statement Document is available to the public through the National Technical Information Services, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 65	22. Price

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

407 080

JR

TABLE OF CONTENTS

	<u>Page</u>
1. EXECUTIVE SUMMARY	3
2. INTRODUCTION	5
3. RESEARCH OBJECTIVE	5
4. MAIN TEXT--EXPERIMENTAL WORK	5
a. Substrates and Surface Preparation	5
b. Selection of Coatings systems	6
(1) Continuation of Immersion Studies from Prior Work	6
(2) Coatings Systems for Steel Buoys	7
(3) Coatings Systems for Aluminum Buoys	8
(4) Coatings Systems for Plastic Buoys	9
(5) Special Coatings Added Late in Program	9
(6) Discussion of New Coatings	9
c. Painting Procedure	12
d. Damage of Panels	13
e. Exposure of Panels	14
f. Performance of Coatings Systems	16
(1) Coatings Systems Rated Outstanding to Excellent	16
(2) Coatings Systems Rated Fair	17
(3) Coatings Systems Rated Unacceptable	18
(4) Physical Properties of Intact and Damaged Coatings	19
g. Composite Ranking of Each Coating System	19
5. RECOMMENDATIONS	20

6. APPENDIX A

TABLE A1. Experimental Buoy Coatings Systems and Panel

Identification

TABLE A2. Gouge and Abrasion Resistances of Coating Systems

TABLE A3. Direct Impact Resistance of Coating Systems

TABLE A4. Supplier Index for Commercial Materials

A-1

A-5

A-6

A-7

Section ☒

Section ☐

UNANNOUNCED

JUSTIFICATION

BY

DISTRIBUTION/AVAILABILITY CODES

Dist. AVAIL and/or SPECIAL

A

TABLE OF CONTENTS (Continued)

	<u>Page</u>
7. APPENDIX B	
Comprehensive Legend for Inspection Reports	B-1
Inspection Report--Marine Immersion Exposure After 18 and 77 Months .	B-2
8. APPENDIX C	
Photographs of Coating Systems After 18 and 77 Months' Immersion . .	C-1

THE EVALUATION OF PROTECTIVE
COATINGS SYSTEMS FOR BUOYS

1. EXECUTIVE SUMMARY. A long-term study of marine coatings systems has been sponsored by the U. S. Coast Guard because of their interest in extending average service life of coatings in the marine environment from two to possibly ten years. In September, 1969, a comprehensive study of premium antifouling marine coating systems was initiated. In May, 1975, this study was expanded to capitalize on data-in-hand and to enter recent developments and new concepts in marine coatings technology into the program.

Exposure studies continued from the prior program have been in progress for 77 months. The performances of seven systems are noteworthy. The vinyl-high rosin specification system Type 121/63 and the elastomeric sheet with organotin toxicant have both been rated outstanding. Performances of the standard vinyl rosin Type 121 specification system, and the self-cured and postcured zinc silicates in high-build vinyl/Type 121 antifoul systems have been excellent. The performances of epoxy/epoxy-coal tar and vinyl rosin with organotin fluoride toxicant are only slightly less. Each of these seven systems were also included in the present study.

The primary service application for the coatings in the present study is buoys. Twenty-three complete anticorrosive antifouling coatings systems have been examined for steel, aluminum, and plastic (rotationally molded, cross-linkable, high-density polyethylene) substrates, which are representative of materials used in buoy construction. To simulate adverse deployment and service conditions, all materials have been subjected to mechanical damage after various immersion times in seawater (exposed near Daytona Beach, Florida). Panels of each coatings system have been damaged by abrasion, impact, and gouge before immersion and others by impact and gouge after 6 and 12 months' immersion. Such treatment has caused no detrimental effect on coatings performance after 18 months' immersion. However, the long-term effects of such damage cannot be ascertained at this time.

Since several years' service are expected from a premium coating system, it is impossible to specifically rate the performance of these systems after only 18 months. At this point in time, the performance of 13 systems have been rated "outstanding to excellent", 3 systems have been rated "fair", and 7 systems have been rated as "unacceptable". A composite ranking for the 13 "outstanding to excellent" performances is possible because 10 of these 13 are direct offsets of the systems in the prior study. They have either been continued up to the present time (77 months' total exposure) or had performed marginally well in the prior study and had been upgraded for inclusion in the present study. The composite ranking, considering material cost, cost of application, performance, special handling conditions, etc, in descending order of preference is as follows.

System	Comment
(1) Type 121/63 vinyl high rosin specification system	Outstanding performance, easy to apply
(2) Elastomeric sheet with organotin toxicant	Outstanding performance, high material costs, labor intensive application, toxic material handling procedures required.
(3) Type 121 standard vinyl rosin specification system	Excellent performance, easy to apply.
(4) Postcure and self-cure zinc silicates with high build vinyl and Type 121 antifoul	More materials to apply than Types 121/63 or 121 and more difficult to handle zinc coat.
(5) Epoxy primer/epoxy-coal tar anticorrosive and antifoul	Excellent performance, unpleasant application and cleanup requirements.
(6) Vinyl rosin; and rosin-chlorinated rubber with organotin fluoride toxicant	Excellent performance, easy to apply.
(7) Polyester glass flake under Type 121 antifoul	Good performance if adhesion obtained. Difficult to apply polyester glass flake.

Three unacceptable systems were nonsolvent polyurethane, toxic organometallic polymer, and flame-sprayed copper cladding. The polyurethane possessed no antifouling properties but excellent corrosion resistance. The organometallic polymer requires additional pigmentation studies to obtain satisfactory adhesion and the copper cladding delaminated from all substrates early in the exposure program.

These data are considered significant because they bring the U. S. Coast Guard's goal of extended service life closer to realization. Service life projections indicate that several candidate materials may be available. Results of this study can be used to upgrade the protective coatings phase of the buoy program. Successful systems should be reduced to practice by developing the study into a test buoy stage. This recommendation and others such as continuing the immersion of the best materials in the program are offered as part of this Final Report.

2. INTRODUCTION. In September, 1969, a study was initiated for the U. S. Coast Guard to evaluate premium coating systems for buoys, ships, and offshore structures. The study was reported in BCL's Report No. CG-D-74-75 of March 21, 1975. After 51 months of seawater immersion at Daytona Beach, Florida, the performance of several coating systems was sufficiently attractive to consider them as candidates for meeting the stringent requirements of the Coast Guard.

Emphasis in that past research program concentrated on identifying coating systems for buoys. Additional studies were indicated to capitalize on data then in hand. To insure the currency of follow-on work, it was necessary to add additional buoy coating systems to the continuing program. Both of these needs were addressed by a new program initiated on June 5, 1975. The discussion of this new program is the subject of this Final Report.

3. RESEARCH OBJECTIVE. The objective of the research program has been the identification of premium antifouling coatings systems for buoys suitable for the U. S. Coast Guard. The research has consisted of (1) selecting potentially long-lived coatings systems for service on steel, aluminum, and plastic substrates; (2) preparing test panels of each system and subjecting them to mechanical damage to simulate adverse service conditions; and (3) evaluating the service performance of the damaged panels after static raft-type, total immersion studies in seawater.
4. MAIN TEXT--EXPERIMENTAL WORK. This study of the performance of new and novel coating systems for buoys has continued earlier work and has expanded its scope to include new materials while placing greater emphasis on substrates other than steel.

- a. Substrates and Surface Preparation. Steel, aluminum, and plastic substrates have been used for test panels.

Steel panels were cut from 1/8-inch hot-rolled stock to a panel size of 6 x 12 inches. All edges were well-rounded to remove any roughness that might adversely affect the performance of the paint systems. The panels were sandblasted to white metal SSPC No. 6 and immediately spray-coated with pretreatment (e.g, 0.5 mil, dry, Formula 117 wash primer) or appropriate primer.

Aluminum panels were cut from marine grade Series 6061 to a size of 6 x 12 x 0.125 inches. The panels were edge sanded similar to the steel panels above and then chemically cleaned according to the following procedure.

- (1) Solvent clean
- (2) Hot dip (160 F) in acid-sodium dichromate bath for 10 minutes

- (3) Soap and water wash
- (4) Tap water rinse
- (5) Deionized water rinse.

Because of favorable buoy experience, Coast Guard personnel suggested a low molecular weight polyethylene ("Marlex CL100", Phillips Petroleum) as the plastic substrate for the program. Test panels were cut from rotationally molded boxes studied by Phillips Petroleum. These panels cut to a 6 x 12-inch size, contained a slight curve of about 1/4 to 1/2 inch across the 6-inch width.

To promote coating adhesion, all plastics test panels were cleaned according to a procedure recommended by Phillips Petroleum as follows.

- (1) Chemically clean by a 2-minute dip in a hot (160 F) sulfuric acid/sodium dichromate bath
- (2) Rinse in tap water
- (3) Rinse in distilled water
- (4) Seal in aluminum foil until ready for painting.

b. Selection of Coatings Systems. The research program has included the evaluation of 31 coatings systems. Eight of these are carried over from the prior program. Eleven new systems for steel, four new systems for aluminum, and five new systems for plastic have been added. Also, three special systems have been added at the request of Coast Guard personnel. Each of these groups is described below and the new materials are discussed in the final section, part 4b(6).

- (1) Continuation of Immersion Studies From Prior Work. Fifteen static immersion panels (14 test panels plus one control panel on steel) representing eight coatings systems were returned to the water after the final (51-month) inspection on program DOT-CG-51331-A. These systems are as follows.

Coating System No.	Description
CG-2	Type 121/63 vinyl-high rosin control
CG-17	Elastomeric sheet with organotin toxicant
CG-1	Type 121 standard vinyl-rosin control
CG-14	Self-cure zinc silicate high-build vinyl, Type 121 antifoul
CS-5	Postcure zinc silicate, high-build vinyl, Type 121 antifoul
CG-14	Vinyl-rosin with organotin (TBTF) toxicant, aluminum substrate
CG-15	Vinyl-rosin with organotin (TBTF) toxicant, fiberglass substrate
CG-11	Epoxy primer, epoxy-coal tar anticorrosive and antifoul

Complete descriptions of these systems are in Appendix Table A1.

- (2) Coatings Systems for Steel Buoys. Eleven coating systems were selected for evaluation on steel substrate. Eight of these have been remade from the prior study (old numbers CG1-18). Numbering system for the new materials was started with CG-19 as noted below.

Coating System No.	Description
New (Old)	
CG-19 (CG-2)	Type 121/63 vinyl high rosin control
CG-20 (CG-17)	Elastomeric sheet with organotin toxicant
CG-21 (CG-1)	Type 121 Standard Vinyl Rosin Control
CG-22 (CG-4)	Self-cure zinc Standard Vinyl Rosin Control

Coating System No.	
New (Old)	Description
CG-23 (CG-5)	Postcure zinc Standard Vinyl Rosin Control
CG-24 (CG-11)	Epoxy primer Standard Vinyl Rosin Control
CG-25 (CG-9)	Type 121 applied quickly (before complete cure) over epoxy primer and anticorrosive
CG-26 (CG-3)	Type 121 applied over sanded polyester glass flake anticorrosive
CG-27 (--)	Rosin-chlorinated rubber with TBTF toxicant over coal tar-epoxy anticorrosive
CG-28 (--)	Flame sprayed copper cladding over polyester glass flake
CG-29 (--)	Acrylic-organometallic toxic polymer over Type 119 anticorrosive.

Complete descriptions are given in Appendix Table A1.

- (3) Coatings Systems for Aluminum Buoys. Four systems were selected for evaluation on 6061 grade aluminum. Two were selected from the prior study because of outstanding performance and two represent new technology which was not available at the start of the old study. No anticorrosive coatings were used on the aluminum substrate.

Coating System No.	Description
CG-30	Elastomeric sheet with organotin toxicant
CG-31	Rosin-chlorinated rubber antifoul with TBTF toxicant
CG-32	Acrylic-organometallic toxic polymer
CG-33	Rosin-chlorinated rubber antifoul with TPTF toxicant

Complete descriptions are given in Appendix Table A1.

- (4) Coatings Systems for Plastic Buoys. Five systems were selected for evaluation on polyethylene panels. These were as follows.

Coating System No.	Description
CG-34	Type 121/63 vinyl-high rosin control
CG-35	Rosin-chlorinated rubber antifoul with TBTF toxicant
CG-36	Acrylic-organometallic toxic polymer
CG-37	Rosin-chlorinated rubber antifoul with TPTF toxicant
CG-38	Flame-sprayed copper cladding

Complete descriptions are given in Appendix Table A1. Also a Supplier Index for Commercial Materials is listed in Table A4.

- (5) Special Coatings Added Late in Program. Three coating systems were added to the program at the request of Coast Guard personnel. A commercial, 100 percent solids, nonsolvent polyurethane coating ("Zebron", Xenex) was applied about 25 mils dry thickness to plastic, steel, and aluminum substrates as System Nos. 39 and 40 and 41, respectively. The material reportedly possessed excellent corrosion resistance, reduced friction resistance, and an interesting degree of antifouling properties.
- (6) Discussion of New Coatings. The selection logic for adding new coating systems to the program is described below.

Organotin Coatings. Excellent, vinyl-rosin and rosin-chlorinated rubber-based antifouling paints can be formulated using organotin toxicants. Two bottom paints with different toxicants, TBTF (tributyltin fluoride) and TPTF (triphenyltin fluoride), have been included in the program. TBTF currently enjoys the best reputation in the U. S. for a single organotin toxicant. It is more toxic and less soluble in seawater than TBTO (tributyltin oxide) and is approved for use in the U. S. It is often used in combination with TBTO as, for example, in the vinyl resin-based

U. S. Navy Formula 1020A. Because TBTO is more soluble in seawater than TBTF, it plasticizes the film and allows TBTF to hydrolyze more completely. However, this requires extremely high toxicant loading levels which present problems of (1) human toxicity during application; (2) unnecessarily high amounts of environmental (seawater) pollution during service; (3) high human toxicity during removal for repair and repainting; and (4) generally inefficient use of toxicant. Because of these unfavorable conditions, the 1020A-type paints have recently fallen into disfavor and, consequently, are not included in the present program.

By adding rosin and using only TBTF as toxicant, the effective loading level of toxicant can be reduced to about 30 percent. This minimizes much of the above problems. Performance data for rosin-chlorinated rubber-based paints using the TBTF toxicant are particularly attractive.

A commercial system of epoxy-coal tar anticorrosive, chlorinated rubber seal coat, and rosin-chlorinated rubber antifouling topcoat with TBTF toxicant was applied to steel (System No. 27). The topcoat was also applied to pretreated aluminum and plastic over a wash primer (System Nos. 31 and 35, respectively).

TPTF exhibits more mammalian toxicity than TBTF. However, this environmental risk is offset by its greatly reduced solubility in seawater. The reported leaching rate of TPTF toxicant in an effective rosin-chlorinated rubber paint is only about 1/40th of that of Formula 1020A-type paints containing TBTO/TBTF toxicants. Therefore the in-service pollution of TPTF is believed to be little different than that of TBTF even though antifouling service lives can be dramatically extended.

TPTF is not approved for commercial use in the U. S. as yet and studies of toxicity to workers are in progress. These paints find usage in Europe and other parts of the world but they must be considered to be in a research and development stage in the U. S.

In the present study, a sample of a commercial rosin-chlorinated rubber antifouling paint with TPTF toxicant was obtained from Denmark. The coating was applied over wash primer on pretreated aluminum and plastic substrates (System Nos. 33 and 37, respectively).

Flame-Sprayed Copper Cladding. Flame spraying was used to apply a copper coating directly on pretreated plastic panels and to polyester-glass flake midcoats on steel (Systems Nos. 38 and 28, respectively). Flame spraying produces a metal coating of about 80 percent theoretical density. Plasma applied coatings increase

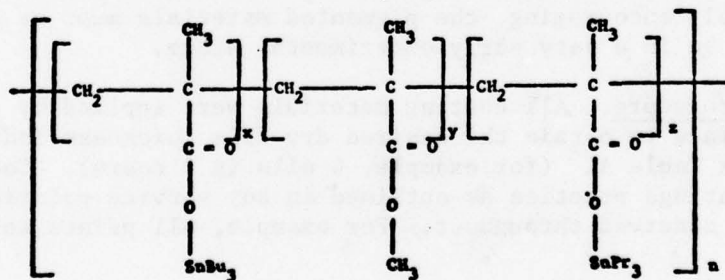
this to 90 percent and the decision is one of selecting an application procedure which will limit the porosity to an acceptable level to maintain adhesion.

Flame spraying, selected for this study, was accomplished at Battelle-Columbus by a four-step procedure.

- (1) Roughen the surface (plastic or polyester-glass flake) by a sweep blast with aluminum oxide at about 15 psi pressure
- (2) Clean with an alcohol rinse
- (3) Deposit a 2-3-mil film of zinc by flame spraying with a Metco 10E gun
- (4) Deposit a 10-mil film of copper from wire by flame spraying with a Metco 10E gun.

Using this procedure, it was calculated that 50 pounds of copper wire will cover 347 square feet at a thickness of 10 mils. The current price of copper wire in research quantities is about \$2.00/lb or about \$0.30/sq ft of coverage. This cost is considered reasonable, especially in light of the potential antifouling service life of a copper metal film together with the outstanding physical properties observed in the final coatings (described below).

Organometallic Methacrylic Polymer. A sample of unpigmented acrylic copolymer (1:1:1 tributyltin methacrylate: methyl methacrylate: tripropyltin methacrylate, 45 NVM in mineral spirits) was obtained from the Naval Ship Research and Development Center, Annapolis, Maryland. A general structure for this polymer is



where x, y, z, and n represent repeating monomeric units, and SnBu_3 and SnPr_3 represent tributyltin and tripropyltin moieties, respectively. NSRDC personnel have developed several of these organometallic polymers which show promise as the chemical foundation for a new generation of marine antifouling materials, particularly for antifouling bottom paints. These new polymeric materials are based on acrylic and vinyl resins which contain toxic moieties of trialkyl and/or triaryl tin compounds. When comparing the activity of these new materials with conventional antifouling coatings, it has been demonstrated that the new unpigmented organometallic polymers possess the capability for longer antifouling service lives and are toxic to a broader range of fouling organisms. Conventional organotin antifouling coatings generally contain a single organometallic salt as a toxicant, for example, tributyltin oxide or fluoride which is physically incorporated into the coating similar to an inert pigment. This technique has proven effective but is not necessarily efficient. By contrast, the chemically bound nature of the toxic moiety in the new polymers reduces its solubility in seawater (leaching rate) and thereby is capable of significantly extending the antifouling service life of a coating. Further, the addition of several chemically bound toxic moieties onto a common resin backbone broadens its scope of antifouling activity.

The polymer sample obtained for this study was pigmented at Battelle-Columbus with titanium dioxide ("TiPure 902", Du Pont) to obtain a 35 percent pigment volume concentration. The resultant white coating was applied to (1) steel (System No. 29) over Type 119 vinyl-red lead anticorrosive and Formula 117 wash primer; (2) aluminum (System No. 32) pretreated as noted above and primed with wash primer; and (3) pretreated plastic (System No. 36) containing wash primer. These coatings possessed good hiding power and film forming characteristics (excellent wetting and drying times). Physical properties are listed in the appropriate section below. Their service performance is unknown because this work is the first known effort to pigment and expose the polymers. However, their performance can be extrapolated from exposure data obtained with the unpigmented polymers. Although exposure data are extremely encouraging, the pigmented materials must be considered to be in a very early experimental stage.

- c. Painting Procedure. All coating materials were applied by spraying the panel face to obtain the desired dry film thickness indicated in Appendix Table A1 (for example, 4 mils in 2 coats). Good organic coatings practice as outlined in any service painting manual was observed throughout. For example, all paints were

applied by a suction gun using normal (20-30 psi) pressure. The gun was maintained at a right angle about 6-8 inches from the panel to insure a good wet film. After a satisfactory fan (spray pattern) was obtained, the paint was applied in multiple passes. In addition to coating the panel face, all panels were also backed and edged according to the above procedure.

All panels were marked for identification stamping a 1/2-inch number into the upper right corner of the panel front. The finished panels were further identified on the back with 6-inch numbers, using Type 129/63 black antifouling paint.

The lab-pigmented organometallic methacrylate coating was applied by brush because of the small volume of material available. Because of the unknown toxicity of this material, special handling precautions were observed in all phases of panel preparation. Plastic panels were coated with the experimental materials applied to the convex side to simulate actual buoy geometry.

- d. Damage of Panels. Several damage situations were selected to simulate the major destructive forces to which a buoy may be subjected during deployment and service; these are impact, gouge, and abrasion. The panels have been subjected to these damaging effects before exposure in seawater and after various lengths of service (immersion in seawater). Seven duplicate panels of each system have been prepared and tested as follows.
- (1) Panel No. 1 - Undamaged Control. This completely coated panel has been used for reference throughout the program to determine the true potential of the coating system in an undamaged situation.
 - (2) Panel No. 2 - Damaged by Impact Before Service. The direct impact resistance of each coating system was determined after a minimum of 14 days aging at ambient conditions. This value and three fractions thereof (for example, 5, 10, and 15 inch-pounds, for an impact resistance of 20"#" were used to damage the four quadrants of a coated 6 x 12-inch panel. This panel was then exposed to seawater in Florida to determine its service potential in these four damaged conditions.
 - (3) Panel No. 3 - Damaged by Impact After 6 Months of Service. The third panel of each system was placed in seawater in Florida, removed after 6 months, damaged as above, and returned to the water.
 - (4) Panel No. 4 - Damage by Impact after 12 Months of Service. The fourth panel of each system was placed in seawater in Florida, removed after 12 months, damaged as above, and returned to the water.

- (5) Panel No. 5 - Damage by Gouge Before Service. Gouge resistance (pencil hardness method) of each coating system was evaluated after a minimum of 14 days' aging at ambient conditions. The fifth panel of each coating system was gouged (about 1/8-1/4 inch square in the center of the 6 x 12-inch panel) and was then exposed in Florida seawater to determine its service potential in this damaged condition.
- (6) Panel No. 6 - Damaged by Gouge After 6 Months of Service. The sixth panel of each coating was placed in Florida seawater, removed from the water after 6 months, gouged similar to Panel 5 above, and returned to the water.
- (7) Panel No. 7 - Damaged by Abrasion Before Service. The abrasion resistance of each coating system was determined after a minimum of 14 days' aging at ambient conditions. This value was used to damage the seventh panel prior to immersion in Florida seawater.

Panel numbers identifying each of the seven conditions for all coating systems are listed in Appendix Table A1.

- e. Exposure of Panels. The coated panels have been exposed in natural seawater at Battelle's Florida Marine Research Facility near Daytona Beach. The panels are secured in standard exposure racks by narrow strips across the 6-inch ends of each panel. They are exposed with the panel surface parallel to the direction of tidal currents. Reference panels, without antifouling coating, have been included to provide a record of attachment to unprotected surfaces. All panels have been examined for blistering, checking, cracking, or peeling of the coatings and for corrosion. Anti-fouling performance has been rated with respect to total fouling and in terms of specific type of fouling (barnacles, mollusks, annelids, filamentous and encrusting bryozoa, hydroids, and algae). Color 35-mm photographs were also taken for recording coating performance.

The first inspection of these 149 panels was conducted on March 10, 1976, after 6 months' seawater immersion in Florida. The second inspection was conducted on September 13, 1976, after 12 months' immersion and the third inspection was conducted on March 18, 1977, after 18 months' immersion. The final inspection of the panels carried over from the prior study was also conducted on March 18, 1977. The inspection culminated 77 months' continuous exposure for these 15 panels.

The entire damage, exposure, and inspection scheme is listed in Table 1.

TABLE 1. TIME SCHEDULE FOR RESEARCH PROGRAM

Date	Panels Continued From Report CG- D-74-75	Activity for Indicated Panel Group New Panels (143) Prepared at BCL					
		Direct Impact Tests		Couging Tests		Abrasion Tests	Exposure Tests
		20 Panels	20 Panels	20 Panels	20 Panels		
Nov. 5, 1975	--	Damage Panels, Start Expo- sure Tests	Immerse	Damage Pan- els, Start Exposure Tests	Immerse	Damage Panels, Start Expo- sure Tests	Immerse
Mar. 10, 1976	Conduct Sixty- Five (65) Month Evaluation	Conduct Six (6) Month Evaluation	Remove from Exposure, Damage, and Return to Exposure	Conduct Six (6) Month Evaluation	Remove from Exposure, dam- age, and Re- turn to Expo- sure	Conduct Six (6) Month Evaluation	Conduct Six (6) Month Evaluation
Sept. 13, 1976	--	Conduct Twelve (12) Month Eval- uation	Conduct Six (6) Month Evaluation	Conduct Twelve (12) Month Eval- uation	Conduct Six (6) Month Evaluation	Conduct Twelve (12) Month Eval- uation	Conduct Twelve (12) Month Evalua- tion
Mar. 18, 1977	Conduct Seventy- Seven (77) Month Evaluation	Conduct Eight- teen (18) Month Eval- uation	Conduct Six (6) Month Evaluation	Conduct Eighteen (18) Month Evaluation	Conduct Twelve (12) Month Evalua- tion	Conduct Eight- teen (18) Month Evalua- tion	Conduct Eighteen (18) Month Evalua- tion

f. Performance of Coatings Systems. After 18 months of total immersion in seawater at Daytona Beach, Florida, it is possible to rank order the performance of all coatings systems into three general groups: (1) Outstanding to excellent, (2) fair, and (3) unacceptable. Each of these groups is discussed below.

- (1) Coatings Systems Rated Outstanding to Excellent. The performance of 13 systems has been rated outstanding to excellent; using a scale of 0-10 where 10 is perfect (no fouling). All ratings for outstanding to excellent coatings (7 panels of each system, both damaged and control) have been at least 10-. This performance was expected because only premium coatings systems had been selected for inclusion in this study. Several more years of exposure data are necessary before the true potential of these systems can be ascertained. However, it is possible to project a comparative rating for at least 8 of these systems based on their performance in the prior study (77 months' exposure data). The systems represented in both studies and their current ratings are as follows.

System No.		Description	Rating	
New Study	Old Study		New Study (18 Month Exposure)	Old Study (77 Month Exposure)
CG20 (steel)	CG17 (rotor panel) (a)	Elastomeric sheet with organotin toxicant	10	10(b)
CG38 (aluminum)			10	
CG19 (steel)	CG2 (steel)	Type 121/63 Vinyl-High Rosin Control	10-	10-
CG22 (steel)	CG4 (steel)	Self-cure zinc silicate/High build vinyl/Type 121 antifoul	10-	8
CG21 (steel)	CG1 (steel)	Type 121 Standard Vinyl Rosin Control	10-	7
CG23 (steel)	CG5 (steel)	Postcure zinc silicate/high build vinyl/Type 121 antifoul	10-	7-
CG24 (steel)	CG11 (steel)	Epoxy primer/Epoxy-coal tar anti-corrosive and antifoul	10-	6+
CG31 (aluminum)	CG14 (aluminum) (c) CG15 (fiberglass)	Vinyl rosin/TBTF toxicant	10-	6 5-

(a) Panel subjected to five 2-month rotor cycles before being placed on static immersion.

(b) Filamentous algae ignored in fouling rating.

(c) Vinyl rosin vehicle in CG14 was upgraded to rosin-chlorinated rubber in CG31.

These coatings are discussed below under "(g) Composite Ranking of Each Coating System".

At the completion of the prior study, the performance of two systems appeared interesting, particularly if intercoat adhesion could be improved. Therefore, in the present study scuff sanding of the anticorrosive and application of topcoat within 8 hours (before complete cure) were used to promote topcoat-midcoat adhesion. The exposure of the old panels was not continued at the end of the prior study. However, the performance of the new offsets (after 18 months' exposure) appears to be as good or better than those of the prior study. These systems are as follows.

System No.		Description	Rating	
New Study	Old Study		New Study (18 month Exposure)	Old Study (51 month Exposure)
CG26	CG3	Type 121 antifoul over polyester glass flake	10	5-
CG25	CG9	Type 121 antifoul over epoxy system	10-	7+

The remaining three systems in the "excellent to outstanding" performance group are new materials which were not available at the beginning of the prior study. These three, all rated 10- after 18 months' exposure, are as follows.

System No.	Description
CG27 (steel)	Rosin-chlorinated rubber antifoul (TBTF toxicant) over coal tar-epoxy
CG35 (plastic)	Rosin-chlorinated rubber antifoul (TBTF toxicant)
CG37 (plastic)	Roxin-chlorinated rubber antifoul (TPTF toxicant) over wash primer

It was observed that the rosin-chlorinated rubber antifoul with TBTF toxicant was one of the easiest materials to handle in the entire program. It possesses excellent application and drying characteristics. Cost is competitive and there are no color limitations. Further exposure studies may prove this material to be of outstanding premium quality.

The material containing TPTF toxicant is considerably more toxic and presents an unknown handling problem. Application characteristics were less than ideal and most cured films possessed an undesirable graininess.

- (2) Coatings Systems Rated Fair. The performances of three systems have been rated as "fair" after 18 months' continuous immersion in seawater at Daytona Beach, Florida. Ratings of "fair" are based on at least half of the seven duplicate (damaged) panels being rated less than 10-. These three systems are as follows.

<u>System No.</u>	<u>Description</u>	<u>No. of Panels Rated Less than 10- After 18 Months' Exposure</u>
CG33 (aluminum)	Rosin chlorinated rubber (TPTF toxicant)	3
CG34 (plastic)	Type 121/63 over wash primer	4
CG38 (plastic)	Flame-sprayed copper cladding	7

All of the copper-coated panels failed by loss of adhesion of the cladding to the substrate.

- (3) Coatings Systems Rated Unacceptable. The performance of seven systems has been rated as unacceptable. All panels were totally fouled or had completely lost topcoat adhesion at the time of the 6-month inspection. These seven systems are as follows.

<u>System No.</u>	<u>Description</u>
CG28 (steel)	Flame-sprayed copper cladding over polyester-flake glass
CG29 (steel)	Acrylic-organometallic polymer over vinyl red lead (Type 119)
CG32 (aluminum)	Acrylic-organometallic polymer over wash primer
CG36 (plastic)	Acrylic-organometallic polymer over wash primer
CG39 (plastic)	Nonsolvent polyurethane
CG40 (steel)	Nonsolvent polyurethane
CG41 (aluminum)	Nonsolvent polyurethane

It is felt that the acrylic-organometallic polymers offer considerable promise as a new class of antifouling materials. Coatings in the present study failed primarily because they were prepared in the laboratory as an early, one-time attempt to obtain satisfactory pigmentation. Large-scale pigmentations studies are currently in progress which could resolve most or all of the problems encountered here. The upgraded materials should be considered for additional buoy studies because they appear to be excellent candidates for meeting all of the U. S. Coast Guard's stringent requirements for buoy materials.

Flame-sprayed copper cladding should be a successful anti-fouling buoy material if adhesion can be improved. Since this also was a one-time laboratory effort, further consideration should be given to follow-on studies.

The nonsolvent polyurethane was found totally lacking in antifouling properties. However, its physical and anti-corrosive properties are outstanding and may justify some effort to obtain antifouling properties as well.

- (4) Physical Properties of Intact and Damaged Coatings. Several damage situations were elected (see 4.d. Damage of Panels) to simulate the damage a buoy coating may be subjected to during deployment and service. After 18 months' immersion in undamaged, predamaged, and damaged-in-service situations, it is possible to draw several important conclusions. Of most importance is the observation that no coating performance was compromised by any of the damaged situations. This is probably due to the premium nature of all of the systems in the program. It does not imply that this relationship will continue to exist after several more years of exposure.

No significant fouling was observed at or on any of the damaged areas of the panels. Therefore, it can be concluded that most of the premium coatings systems have sufficient "throwing power" to protect small (up to 1/4 inch square) damage spots from initiating total failure. Again, this ability may be severely compromised as immersion times progress.

Complete gouge and abrasion resistance data are listed in Appendix Table A2 and complete impact resistance data are listed in Appendix Table A3.

- (g) Composite Ranking of Each Coating System. It is difficult to prepare a composite ranking of long-term service buoy coatings after only 18 months' evaluation. However, performance has been generally rated above as excellent to outstanding (13 systems), fair (3 systems), and unacceptable (7 systems). These performance ratings can be used as a starting point in establishing composite rankings for the coatings systems. Within the best group of 13 systems, it is possible to extrapolate service potential by considering the performance of similar systems in the prior study after 77 months of exposure. It is also possible to comment briefly on those systems which are cost prohibitive, labor intensive in application, or require special handling conditions because of toxicity.

Based on this type of information, the composite rating scheme listed below has been prepared. Systems are listed and discussed in descending order of desirability.

- (1) Type 121/63 and Type 121 Antifoul Over Type 119 Vinyl-Red Lead Anticorrosive and Type 117 Wash Primer. These two systems (CG2 and 1 in old study and CG19 and 21 in present study) appear the most desirable of all materials in the program for many reasons. Their performance is consistently

outstanding. They are state-of-the-art materials which can be applied using conventional application equipment. No unusual care must be taken with these materials other than that dictated by good coatings practice. It should be noted that the unusually good performances of the Types 121/63 and 121 are undoubtedly due to the extra care taken in panel preparation in the laboratory. Therefore, even though no unusual care is required, attention to every detail of good coatings practice will measurably improve the performance of these systems. The cost of these two systems is within the normal range of today's standard marine coatings. Because of consistent better performance, the composite ranking for Type 121/63 should be considered superior to that of Type 121. These specification systems were developed for maximum performance on steel substrate. Therefore, it is important to specify the Type 117 wash primer to obtain good adhesion and to specify the Type 119 midcoat to obtain good resistance to corrosion. The vinyl-red lead anticorrosive (Type 119) is particularly effective in aggressive tropical marine climates. However, the service life of all antifouling coatings is adversely affected by hot tropical waters and the Type 121 and Type 121/63 are not exceptions. Limited color coding of the antifouling topcoats would be possible with a modest formulation study.

Of interest is the performance of the Type 121/63 system on plastic substrate (System CG-34). After 18 months of immersion, three of the damaged CG34 panels are rated 10- but one is rated 8 and two others are rated 7 for fouling. There is a trace of peeling present which indicates that there may be a long-term adhesion problem over plastic. Further study is required before valid conclusions can be made.

- (2) Elastomeric Sheet with Organotin Toxicant. This system (CG-20 and 30 in present study and CG17 in prior study) possesses the greatest service life potential of any system in both studies. It would appear to offer potential for the 10 years' resistance to fouling and corrosion desired by the USCG. The actual performance mechanism is not fully understood. In addition to the slow dissolution of toxicant in seawater, its success is probably due to a combination of factors such as the inability of macroscopic fouling organisms to establish a firm attachment on the elastomeric sheet.

The manufacturer prefers the term "diffusion" to "leaching rate" when describing the functioning of this product. It is reported that the diffusion rate is temperature dependent and, to a lesser degree, influenced by water velocity. Thus, while the material appears ideally suited to service in temperate, subtropical waters, it may not perform well at Pearl Harbor or in extremely cold waters.

Economic studies conducted by the manufacturer of using "No Foul" instead of a coating system on a vessel the size of a small destroyer indicate a cost trade-off after about 3 years of service. This may be appreciably sooner if allowance is made for fuel penalty at current market prices. A common fuel penalty figure cited for a destroyer-sized hull is about 13 percent per year. Toxic handling precautions are required but the material does not present the same magnitude of environmental pollution problems as antifouling paints containing organotin toxicants. Pollution of shipyard atmosphere during application and repair and of seawater during service are both minimal.

Two major factors which must be considered are material and application costs. Initial material costs are high. In addition to the elastomeric sheet and adhesive coating, conventional primer and anticorrosive coatings must be applied. Cutting and fitting the elastomeric sheet is highly labor intensive and required additional skills beyond those of paint spraying. For these reasons the composite ranking of this material must be considered somewhat lower than that of Type 121/63 and probably equal to that of Type 121.

It has been demonstrated by this study that the material will withstand a significant amount of physical abuse in deployment and service and still perform satisfactorily. Color coding is limited to black.

- (3) Self-Cure and Postcure Zinc Silicates Under High Build Vinyl and Type 121 Antifoul. These two systems (CG4 and 5 in prior study and CG22 and 23 in present study) have performed unusually well in both studies. The material costs of both are slightly higher than the Type 121/63 and 121 systems but they are not as expensive as the elastomeric sheet. They are more difficult to apply than the Types 121/63 and 121 because there are more components in the system (zinc/tiecoat/high build vinyl/antifouling topcoat) and because it is more difficult to apply the heavy zinc coat than conventional paints. For these reasons their composite rankings are lower than the Types 121/63 and Type 121 and that of the elastomeric sheet. Limited color coding is possible as mentioned for the Type 121 topcoat, above.
- (4) Vinyl Rosin/TBTF Toxicant. This system (CG14 in prior study and CG31 in present study) is very easy to apply and has no serious shortcomings other than its slightly poorer performance than the materials listed above. Its raw material costs will be slightly less than those of the Types 121/63 and 121. Broad color coding potential exists.

(5) Epoxy Primer/Epoxy-Coal Tar Anticorrosive and Antifoul.

This system (CG11 in prior study and CG24 in present study) is a premium material which should perform as well as the vinyl rosin (g(4), above). However, workers often complain of the difficulties and unpleasantness of applying the thick coal tar midcoat. The system certainly should be considered for buoys in still, brackish waters where its heavy film thickness is an advantage.

Sufficient data are not available on the remaining systems to assign them a composite rating. It may be possible to significantly upgrade the performance of those systems rated as unacceptable, particularly the copper cladding, toxic organometallic polymer, and nonsolvent polyurethane. It was not within the scope of the present program to consider such modifications.

5. RECOMMENDATIONS. Several recommendations for taking optimum advantage of current data are now possible. It is important to reduce to practice the coatings systems where performances have been rated outstanding to excellent. Replicate test buoys should be prepared for service in different temperature waters. Buoy size and composition should be selected as quickly as possible for these evaluations.

A minimum research program should be considered to continue the exposure of the best panels currently on test at Daytona Beach, Florida. This would include about 10 panels from the prior study and about 30 panels from the present study. This is of paramount importance because no coatings systems have yet to be exposed for the full term of the projected 10-year goal.

Second priority should be placed on improving the performance of systems which failed early in the present program. A modest program could be undertaken to provide some measure of fouling resistance to the nonsolvent polyurethane system. The U. S. Navy toxic organometallic polymer has been the subject of several pigmentation studies and the most successful formulation could be added to the buoy program. Inquiries could be made into the possibility of increasing the film density and the topcoat adhesion of the flame-sprayed copper cladding. In addition, the door should be left open to enter new commercial materials into the program as they became available.

6. APPENDIX A

TABLE A4. SUPPLIER INDEX FOR COMMERCIAL MATERIALS

Material	Supplier	Product Description	Material Used in Coating System (CG Nos.)
Type 121, MIL-P-15931A	Reliance Paint Brooklyn, New York	Standard, vinyl-rosin antifouling (CU ₂ O toxicant)	21, 22, 23, 24, 25, 26
Type 121/63, MIL-P-15931B	Reliance Paint Brooklyn, New York	Vinyl-high rosin antifouling (CU ₂ O toxicant)	19, 34
No foul	B. F. Goodrich Company Akron, Ohio	Elastomeric sheet antifouling (organotin toxicant)	20, 30
VIP 0733-5140	Hempel's Marine Paints New York, New York	Rosin-chlorinated rubber antifouling (TBTF toxicant)	27, 31, 35
VIP 7640-5140	Hempel's Marine Paints New York, New York	Rosin-chlorinated rubber antifouling (TPTF toxicant)	33, 37
Metalast 915	Woolsey Marine New York, New York	Vinyl-red lead anticorrosive, MIL-P-15929B	19, 21, 29
Catha-Coat 302 Primer	Devoe Marine Division Devoe Raynolds New York, New York	Self-curing zinc silicate primer	22
MD 3542	Devoe Marine Division Devoe Raynolds New York, New York	Vinyl high build anticorrosive	22, 23
Tarset Standard	Porter Paint Louisville, Kentucky	Coal tar-epoxy anticorrosive	24
Formula 201	Devoe Marine Division Devoe Raynolds New York, New York	Epoxy anticorrosive	25

TABLE A4. (Continued)

Material	Supplier	Product Description	Material Used in Coating System (CG Nos.)
Formula 204	Devoe Marine Division Devoe Raynolds New York, New York	Epoxy intermediate	25
RES-N-GLAS	Woolsey Marine New York, New York	Polyester-glass flake anticorrosive	26, 28
Hempadur 1513-1999	Hempel's Marine Paints New York, New York	Coal tar-epoxy anticorrosive	27
Shipyard Primer	Porter Paint Louisville, Kentucky	Epoxy primer	24
Zinc-Seal MD 2953 R	Devoe Marine Division Devoe Raynolds New York, New York	Primer-tiecoat	22
No. 54 Tiecoat	Amercoat Corporation Brea, California	Tiecoat	23
Hempatex Primer 1631-4127	Hempel's Marine Paints New York, New York	Tiecoat	27
HLN 12A Primer/HLN 30 Cement	B. F. Goodrich Company Akron, Ohio	Primer/adhesive for no foul	20, 30
Phos-Pho-Neal 31-G-6	Midland Division Dexter Corporation Hayward, California	Formula 117 wash primer MIL-P-15328B	19, 21, 29, 31, 32, 33, 34, 35, 36, 37
Zebron	Xenex Corporation	Nonsolvent polyurethane	39, 40, 41

TABLE A1. EXPERIMENTAL BUOY COATINGS SYSTEMS AND PANEL IDENTIFICATION (a)

BCL Coating No. (b)	Description of Coating System (c)				BCL (d) Panel No.	Test Sequence for Indicated Panel
	Substrate (e)	Pretreatment	Primer and/or Anticorrosive Coating	Antifouling Topcoat		
19 (CG2)	Steel	MIL-P-15328B (Formula 117 Wash Primer) 0.5 mil--1 coat	MIL-P-15929B Formula 119, Vinyl Red Lead, 7 mils in 4 coats	Type 121/63 Vinyl-High Rosin, MIL-P-15931B (3 mils, 2 coats of 1.5 mils each)	40 41 42 43 44 45 46	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse
20 (CG17)	Steel	None	Proprietary Adhesive System (1) Primer (2) Tiecoat (3) Adhesive	Elastomeric Sheet with Organotin toxicant (1 layer--80 mils)	82 83 84 85 86 87 88	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse
21 (CG1)	Steel	MIL-P-15328B (Formula 117 Wash Primer) 0.5 mil--1 coat	MIL-P-15929B Formula 119, Vinyl Red Lead, 7 mils in 4 coats	Type 121 Vinyl-Rosin, MIL-P-15931A (3 mils, 2 coats of 1.5 mils each)	33 34 35 36 37 38 39	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse
22 (CG4)	Steel	None	(1) Self-cure zinc silicate 3 mils--1 coat (2) Primer-tiecoat 1.5 mils--1 coat (3) Vinyl High Build 4 mils--1 coat	Type 121 (3 mils, 2 coats of 1.5 mils each)	54 55 56 57 58 59 67	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse
23 (CG5)	Steel	None	(1) Postcure zinc silicate 2.5 mils--1 coat (2) Tiecoat (3) Vinyl High Build 4 mils--1 coat	Type 121 (3 mils, 2 coats of 1.5 mils each)	60 61 62 63 64 65 66	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse
24 (CG11)	Steel	None	(1) Epoxy Primer (0.5 mil--1 coat) (2) Coal Tar-Epoxy Intermediate (6 mils--1 coat)	Type 121 (3 mils, 2 coats of 1.5 mils each)	75 76 77 78 79 80 81	Control Impact, immerse Immerse, impact at 6 months Immerse, impact at 12 months Gouge, immerse Immerse, gouge at 6 months Abrade, immerse

TABLE A1. (Continued) (a)

BCL Coating No. (b)	Description of Coating System (c)				BCL (d) Panel No.	Test Sequence for Indicated Panel
	Substrate (e)	Pretreatment	Primer and/or Anticorrosive Coating	Antifouling Topcoat		
25 (CG9)	Steel	None	(1) Epoxy Anticorrosive (2 mils--1 coat) (2) Epoxy Anticorrosive Intermediate (4 mils, 2 coats of 2 mils each)	Type 121(f) (3 mils, 2 coats of 1.5 mils each)	68 69 70 71 72 73 74	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>
26 (CG3)	Steel	None	Polyester Glass Flake (g) 30-32 mils--1 coat	Type 121 (4.5 mils, 3 coats of 1.5 mils each)	47 48 49 50 51 52 53	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>
27	Steel	None	Coal tar-epoxy (10-12 mils--1 coat) Tiecoat (1.5-2.0 mils)	Rosin-chlorinated rubber antifoul (TBT toxicant) 4 mils in 2 coats	89 90 91 92 93 94 95	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>
28	Steel	None	Polyester-flake glass (j)	Flame sprayed copper cladding	96 97 98 99 100 101 102	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>
29	Steel	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	MIL-P-15929B Formula 119 Vinyl Red Lead, 7 mils in 4 Coats	Acrylic-organometallic toxicant polymer(h) (3 mils in 4 coats)	103 104 105 106 107 108 109	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>
-(Control)	Steel	None	None	None	110	Uncoated control panel
30 (CG17)	Aluminum	None	Proprietary Adhesive System (1) Primer (2) Tiecoat (3) Adhesive	Elastomeric Sheet (1 layer--80 mils)	111 112 113 114 115 116 117	<u>Control</u> <u>Impact, immerse</u> <u>Immerse, impact at 6 months</u> <u>Immerse, impact at 12 months</u> <u>Gouge, immerse</u> <u>Immerse, gouge at 6 months</u> <u>Abrade, immerse</u>

TABLE AI. (Continued)(a)

BCL Coating No. (b)	Description of Coating System (c)			BCL (d) Panel No.	Test Sequence for Indicated Panel
	Substrate (e)	Pretreatment	Anticorrosive Coating		
31 (CG14) (1)	Aluminum	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Rosin-chlorinated rubber antifoul (TPTF toxicant) 4 mils in 2 coats	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
32	Aluminum	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Acrylic-organometallic toxicant polymer (h) (3 mils in 4 coats)	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
33	Aluminum	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Rosin-chlorinated rubber antifoul (TPTF toxicant) 4 mils in 2 coats	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
-(Control)	Aluminum	None	None	Uncoated control panel	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
34	Plastic	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Type 121/63 Vinyl-High Rosin, MIL-P-15931B (3 mils, 2 coats of 1.5 mils each)	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
35	Plastic	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Rosin-chlorinated rubber antifoul (TPTF toxicant) 4 mils in 2 coats	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse
36	Plastic	MIL-P-15328B (Formula 117) Wash Primer 0.5 mil--1 coat	None	Acrylic-organometallic toxicant polymer (h) (3 mils in 4 coats)	Control
					Impact, immerse
					Immerse, impact at 6 months
					Immerse, impact at 12 months
					Gouge, immerse
					Immerse, gouge at 6 months
					Abrade, immerse

TABLE A1. (Continued) (a)

BCL Coating No. (b)	Substrate (e)	Description of Coating System (c)		BCL (d) Panel No.	Test Sequence for Indicated Panel
		Pre-treatment	Primer and/or Anticorrosive Coating		
37	Plastic	MIL-P-15328R (Formula 117) Wash Primer 0.5 mil--1 coat	None	161 162 163 164 165 166 167	Control Impact, immerse Impact at 6 months Impact at 12 months Gouge, immerse Gouge, immerse Gouge at 6 months Abrade, immerse
38	Plastic	None (j)	None (j)	168 169 170 171 172 173 174	Control Impact, immerse Impact at 6 months Impact at 12 months Gouge, immerse Gouge, immerse Gouge at 6 months Abrade, immerse
39	Plastic	(k)	Nonsolvent polyurethane		
40	Steel	(k)	Nonsolvent polyurethane		
41	Aluminum	(k)	Nonsolvent polyurethane		
-(Control)	Plastic	None	None	175	Uncoated control panel

(a) Original data are in BCL Laboratory Record Notebook No. 32026.

(b) Coating systems are numbered consecutively from 19 to 38. Number from prior study appears in parenthesis where system is unchanged.

(c) Index of Commercial Materials is given in Table A4.

(d) Steel and aluminum panels were stamped with a 1/2-inch number in the upper left hand corner of the panel face. A large number was hand-painted using a contrasting color antifouling paint across the panel back. Plastic panels were numbered with a large hand-painted number across the panel back.

(e) All test panels were cut to 6 x 12 inches. Steel panels are hot rolled 1/8-inch plate; aluminum panels are grade 6061, 1/4-inch thick; and plastic panels are polyethylene about 1/4-inch thick.

(f) To improve topcoat adhesion, the first coat was applied as quickly as possible to the epoxy intermediate coat (at least 16 but no sooner than 6 hours).

(g) To improve topcoat adhesion, the cured polyester-glass flake coating was roughened with #100 sand paper before applying first coat of topcoat.

(h) Prepared in BCL laboratory.

(i) Stamped panel numbers appear in upper left hand corner of panel back.

(j) Cladding procedure described in text.

(k) Applied by manufacturer ("Zebron", Xenex Corporation).

(l) Vinyl rosin vehicle for CG14 was upgraded to rosin-chlorinated rubber for CG-31.

TABLE A2. GOUGE AND ABRASION RESISTANCES OF COATING SYSTEMS

Coating System No. (a)	Descriptive Feature of Coating System (b)	Substrate (c)	Gouge Resistance (d)		Abrasion (e) Resistance, (minutes to fail)
			Before Immersion	After 6 Months' Immersion	
CG19	Type 121/63 vinyl-high rosin antifoul (Cu ₂ O toxicant)	steel	9	9	1.17
CG20	Elastomeric sheet antifoul (organotin toxicant)	steel	(f)	(f)	(f)
CG21	Type 121 standard vinyl-rosin antifoul (Cu ₂ O toxicant)	steel	9	8	0.33
CG22	Self cure zinc silicate, high-build vinyl, Type 121 antifoul (Cu ₂ O toxicant)	steel	3	5	0.33
CG23	Postcure zinc silicate, high-build vinyl, Type 121 antifoul (Cu ₂ O toxicant)	steel	2	4	0.33
CG24	Epoxy primer, epoxy-coal tar anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	10	10	0.25
CG25	Epoxy anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	11	9	0.51
CG26	Polyester-flake glass anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	>17	>17	0.17
CG27	Epoxy-coal tar anticorrosive, chlorinated rubber antifoul (TFTF toxicant)	steel	12	10	1.33
CG28	Polyester-flake glass anticorrosive, flame-sprayed copper antifoul	steel	>17	>17	>10.0
CG29	Vinyl-red lead anticorrosive, acrylic antifoul (organometallic toxicant)	steel	9	(fouled)	0.6
CG30	Elastomeric sheet (organotin toxicant)	aluminum	(f)	(f)	(f)
CG31	Rosin-chlorinated rubber antifoul (TFTF toxicant)	aluminum	9	10	1.66
CG32	Acrylic antifoul (organometallic toxicant)	aluminum	9	10	0.66
CG33	Rosin-chlorinated rubber antifoul (TPTF toxicant)	aluminum	12	12	1.40
CG34	Type 121/63 vinyl-high rosin antifoul (Cu ₂ O toxicant)	plastic	10	8	0.92
CG35	Rosin-chlorinated rubber antifoul (TBTf toxicant)	plastic	3	5	1.66
CG36	Acrylic antifoul (organometallic-toxicant)	plastic	9	11	0.92
CG37	Rosin-chlorinated rubber antifoul (TPTF toxicant)	plastic	10	10	1.40
CG38	Flame-sprayed copper antifoul	plastic	>17	>17	>10.0

(a) Original data are in BCL Laboratory Record Book No. 32026.

(b) Complete descriptions of coating systems are given in Table A1.

(c) Substrates are hot-rolled steel sand-blasted to white metal, aluminum grade 6061 etched in hot sulfuric acid/sodium dichromate bath, and polyethylene ("CL100", Phillips Petroleum) etched in hot sulfuric acid/sodium dichromate bath.

(d) Gouge resistance evaluated by pencil hardness. Number recorded is one lower than that required to gouge coating; the higher the number, the harder the coating.

(e) Abrasion resistance was evaluated by a modification of ASTM Procedure D658. The value recorded is the time required to wear a 2-mm hole through the coating. The higher the number, the more abrasion-resistant the coating.

(f) Unable to obtain realistic value because of elastomeric nature of material.

TABLE A3. DIRECT IMPACT RESISTANCE OF COATING SYSTEMS

Coating System No.	Descriptive Feature of Coating System (a)	Substrate	Before Immersion						Direct Impact Resistance (inch pounds) ^(b)						After 12 Months' Immersion	
			Value	Selected Damage Values (c)	Value	Selected Damage Values (c)	Value	Selected Damage Values (c)	Value	Selected Damage Values (c)	Value	Selected Damage Values (c)	Value	Selected Damage Values (c)	Value	Selected Damage Values (c)
CC19	Type 121/63 vinyl-high rosin antifoul (Cu ₂ O toxicant)	steel	4	3	2	1	20	15	10	5	64	32	16	8		
CC20	Elastomeric sheet antifoul (organotin toxicant)	steel	240 ^(d)	180	120	60	(d)	-	-	-	(d)	-	-	-		
CC21	Type 121 standard vinyl-robin antifoul (Cu ₂ O toxicant)	steel	4	3	2	1	40	30	25	20	64	32		8		
CC22	Self cure zinc silicate, high-build vinyl, Type 121 antifoul (Cu ₂ O toxicant)	steel	5	4	3	2	20	15	10	5	80	40	20	10		
CC23	Postcure zinc silicate, high-build vinyl, Type 121 antifoul (Cu ₂ O toxicant)	steel	5	4	3	2	20	15	10	5	96	48	24	12		
CC24	Epoxy primer, epoxy-coal tar anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	5	4	3	2	20	15	10	5	80	40	20	10		
CC25	Epoxy anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	6	5	4	3	20	15	10	5	Not Tested					
CC26	Polyester-flake glass anticorrosive, Type 121 antifoul (Cu ₂ O toxicant)	steel	8	6	4	2	30	20	10	5	120	60	30	15		
CC27	Epoxy-coal tar anticorrosive, chlorinated rubber antifoul (TBTf toxicant)	steel	16	12	8	4	30	25	20	15	120	60	30	15		
CC28	Polyester-flake glass anticorrosive, flame-sprayed copper antifoul	steel	40	30	20	10		Fouled				Fouled				
CC29	Vinyl-red lead anticorrosive, acrylic antifoul (organometallic toxicant)	steel	6	5	4	3		Fouled				Fouled				
CC30	Elastomeric sheet (organotin toxicant)	aluminum	240 ^(d)	180	120	60	(d)	-	-	-	(d)	-	-	--		
CC31	Rosin-chlorinated rubber antifoul (TBTf toxicant)	aluminum	20	15	10	5	50	40	30	20	150	75	50	25		
CC32	Acrylic antifoul (organometallic toxicant)	aluminum	4	3	2	1		Fouled				Fouled				
CC33	Rosin-chlorinated rubber antifoul (TPTF toxicant)	aluminum	48	36	24	12	80	40	20	10	160	80	40	20		
CC34	Type 121/63 vinyl-high rosin antifoul (Cu ₂ O toxicant)	plastic	10	8	6	4	40	20	10	5	120	80	40	20		
CC35	Rosin-chlorinated rubber antifoul (TBTf toxicant)	plastic	60	45	30	15	50	30	15	10	160	80	40	20		
CC36	Acrylic antifoul (organometallic-toxicant)	plastic	16	12	8	4		Fouled				Fouled				
CC37	Rosin-chlorinated rubber antifoul (TPTF toxicant)	plastic	40	30	20	10	50	40	30	20	164	82	41	20		
CC38	Flame-sprayed copper antifoul	plastic	40	30	20	10		Coating Destroyed				Coating Destroyed				

(a) Complete descriptions of coating systems are given in Table A1.

(b) Direct impact resistance was measured by dropping a weight through a measured distance onto an impactor with a 3/8-inch rounded tip which was in direct contact with the coating. The value recorded was the greatest force in inch/pounds which the coating could withstand without fracture.

(c) Lesser values (below point of impact resistance) were selected to evaluate the effect of slight damage on submerged surfaces. Panels were marked into four quadrants and were damaged, running clockwise starting in the upper right hand quadrant, from smallest to largest value (for example, values of 1234 would be placed on upper right, lower right, lower left, and upper left quadrants, respectively).

(d) No meaningful value possible because of elastomeric nature of material. Original value recorded to allow immersion of damaged panel.

7. APPENDIX B

COMPREHENSIVE LEGEND FOR INSPECTION REPORTS

INSPECTION REPORT--MARINE IMMERSION
EXPOSURE AFTER 18 AND 77 MONTHS

7. APPENDIX B

COMPREHENSIVE LEGEND FOR INSPECTION REPORTS. The performance of each system has been subjectively rated periodically for resistance to fouling and corrosion. To evaluate fouling resistance, note was made of the presence of scum and silt and of a slime film, generally accepted as the precursor and nutrient broth for the macroscopic fouling community. The presence of macroscopic organisms (barnacles, mollusks, annelids, hydroids, and encrusting and filamentous bryozoa) were reported by subjective ratings of 0 to 10 where 10 = perfect, no fouling, and 0 = complete failure. Major factors considered for ratings are the area of the panel fouled (covered by organisms) and the average size (reported in inches) of individual organisms. For example, a panel with seed barnacles about 1/8-inch diameter located mainly at the panel edges would be recorded as "ME, 1/8 inch" and might be rated 8 (80 percent of surface area not fouled). These individual ratings for the activity of each organism were then averaged to obtain a 0 to 10 "general performance" rating of fouling resistance.

Corrosion was evaluated by noting: (1) the location and amount of blistering; (2) the amount of intercoat and "through" peeling (to panel); (3) the location and amount of corrosion; and (4) the presence of eroding, chalking, cracking, or alligatoring of the film. Note was also made of the presence of topcoat and primer surface areas still intact.

The general performance ratings for fouling resistance are considered the most important and are carried to the text of the report. However, the ratings are subjective and only indicate comparative performance for a specific test panel exposed in a specific location during a specific time period. So many dynamic factors influence performance that constant guard should be maintained against making sweeping generalizations from limited data.

INSPECTION REPORT--MARINE IMMERSION EXPOSURE AFTER 18 AND 77 MONTHS.
Table 1B (17 pages) covers this inspection report.

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Company G 6100-0002
 Code Number
 Date placed on test 9-30-75
 Date this inspection 3-17-77

Legend: 10 = Perfect; 0 = Complete Failure
 S - SEED; P - PINPOINT; E - EDGE; CR - CREEPING;
 L - LOOSE; ML - MAINLY LOOSE; LT - LOOSE & TIGHT;
 RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
 10 EXISTED AT PREVIOUS INSPECTION
 DASH (—) INDICATES THAT RATING CANNOT BE DETER-
 MINED DUE TO SOME OTHER CONDITION. TR = Trace

PANEL NUMBER	FOULING DESCRIPTION RATING: 10 TO 0, 0 = COMPLETE FOULING										PAINT CONDITION RATING: 10 TO 0, 0 = COMPLETE FAILURE						% AREA COATING INTACT
	GEN. PER- FORM- ANCE	BARNACLES	MOLLUSKS	ANNELIDS	HYDROIDS	ENCRUST- ING	BRYOZOA	FILAMEN- TOUS	SCUM AND SILT	BLISTERING	PEELING	CORROSION	Chalk- ing	Crack- ing	Alliga- toring	TOPCOAT	PRIMER
		RATING	SIZE	RATING	SIZE	RATING	SIZE	RATING	SIZE	EDGE	TO INTER- COAT	EDGE	TO PAINT- EL	EDGE	Chalk- ing	Crack- ing	
40	10- TR	E 1/2		10- 1 1/4	5 CR.				5 10-	—		5					99
33	10-				7				9 "	9	1/2	9					92
54	10-				8				9 "	9	1/2	5					95
60	10-				8				9 "			10-					100-
75	10-	ME 1/2		10-1	7				8 "	10-10-	1/2	5					98
68	10- TR	1/2			8				9 "	10-10-	1/2	9					95
47	10				7				9 "	0		10-					10?
89	10								TR "	ME 10-		10-TR					98
96	0	Mainly barnacles			few annelids				"			Obscured by fouling					—
103	0								"			—do—					—

Recorded

Florida Marine Research Laboratories
BATTELLE MEMORIAL INSTITUTE
DAYTONA BEACH, FLA.

17 Pages: Page 4

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Company
Code Number G-6100-2
Date placed on test 9-30-75
Date this inspection 3-17-77

Legend: 10=Perfect; 0=Complete Failure
S - SEED; P - PINPOINT; E - EDGE; CR - CREEPING;
L - LOOSE; ML - MAINLY LOOSE; LT - LOOSE & TIGHT;
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

FOULING DESCRIPTION										PAINT CONDITION															
RATING: 10 TO 0, 0=COMPLETE FOULING										RATING: 10 TO 0, 0=COMPLETE FAILURE															
PANEL NUMBER	GEN. PER- FORM- ANCE	BARNACLES		MOLLUSKS		ANNELIDS		HYDROIDS		ENCrust- ING RATING	BRYOZOA FILAMEN- TOUS RATING	ALGAE	SCUM AND SILT	BLISTERING		PEELING TO INTER- COAT	CORROSION		EROD- ING	CHALK- ING	CRACK- ING	ALLIG- ATORING	% AREA COATING INTACT		
		RATING	SIZE	RATING	SIZE	RATING	SIZE	RATING	SIZE					EDGE	GEN.		EDGE	GEN.					TOPCOAT	PRIMER	
119	10-	E 1/4- 10-	10-									5	10-											100-	
126	0			Heavily fouled, mainly barnacles								-												-	
141	10-	E 1/4- 10-	10-			1/2- 10-	2- 0	CR.				9					10-							99	
148	10											7												100	
155	0			Heavily fouled - mainly barnacles								-												-	
169	7	7	1/2	1/4- 7		9	1					-												50?	
83	10																							100	
112	10																							100	
133	10-	E 1/4- 10-	10-									0												100-	
162	10-											0												100	

**Florida Marine Research Laboratories
BATTELLE MEMORIAL INSTITUTE
DAYTONA BEACH, FLA.**

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Legend: 10 = Perfect; 0 = Complete Failure
S = SEED; P = PINPOINT; E = EDGE; CR = CREEPING;
L = LOOSE; ML = MAINLY LOOSE; LT = LOOSE & TIGHT.
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

Company
Code Number *G.6100-z*
Date placed on test *9-30-75*
Date this inspection *3-17-77*

[illegible]

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Company

Code Number G6100-2

Date placed on test 9-30-75

Date this inspection 3-17-77

Legend: 10 = Perfect; 0 = Complete Failure
S = SEED; P = PINPOINT; E = EDGE; CR = CRACKING;
L = LOOSE; ML = MAINLY LOOSE; LT = LOOSE & TIGHT;
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION

[illegible]

DAYTONA BEACH, FLA.

Company

G-6100-2

9-30-75

3-17-77

Legend: 10 = Perfect; 0 = Complete Failure
S - SEED; **P** - PINPOINT; **E** - EDGE; **CR** - CREEPING;
L - LOOSE; **ML** - MAINLY LOOSE; **LT** - LOOSE & TIGHT.
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN 10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETERMINED DUE TO SOME OTHER CONDITION.

FOULING DESCRIPTION										PAINT CONDITION													
RATING: 10 TO 0, 0=COMPLETE FOULING										RATING 10 TO 0, 0=COMPLETE FAILURE													
PANEL NUMBER	GEN. PER-FORMANCE	BARNACLES		MOLLUSKS		ANNELIDS		HYDROIDS		BRYOZOA		FILM ALGAE	SCUM AND SILT	BLISTERING		PEELING TO INTER-COAT	CORROSION		CRACK 100	CHALK 100	EROS 100	% AREA COATING INTACT	
		RATING	SIZE	RATING	SIZE	RATING	SIZE	ENCrust-ING	FILAMEN-TOUS	RATING	SIZE			EDGE	GEN.		TO PAN-EL	EDGE				GEN.	TOPCOAT
42	10							5	1R.			9	10-	9	4-1		8	TR.					98
35	10-TR.		E 1/4-1/2					6	"			10-	1	7	10-1		5	TR.					94
56	10							9	"			10-	1	9	10-1		5	TR.					96
62	10							9	"			9					8					100-	
77	9							5	"			10-				9	9	TR.					94 100-
70	10-10-		E 1/8-1/2					8	"			10-		10-	9	10-1/2	5	TR.					90
49	10							8	"			10-		-	5	10-1/2	TR.						50
91	10							10-	"			7		9	10-1/2		10-TR.						98
98	0							Mainly barnacles								Obscured by fouling							-
105	0							-do-									-do-						-

11 Pages: Page 10

DAYTONA BEACH, FLA.

Legend: 10=Perfect; 0=Complete Failure
S = SEED; P = PINPOINT; E = EDGE; CR = CRACKING;
L = LOOSE; ML = MAINLY LOOSE; LT = LOOSE & THIN;
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

FOULING DESCRIPTION RATING: 10 TO 0, 0=COMPLETE FOULING														PAINT CONDITION RATING: 10 TO 0, 0=COMPLETE FAILURE													
PANEL NUMBER	GEN. PERFORMANCE	BARNACLES		MOLLUSKS		ANNELIDS		HYDROIDS		BRYOZOA		SCUM AND ALGAE	BLISTERING	PEELING		CORROSION		CHECK 100	CRACK 100	ALLOWANCE	% AREA COATING IMPACT						
		RATING	SIZE	RATING	SIZE	RATING	SIZE	ENCrustING	FILAMENTOUS	RATING	SIZE			EDGE	GEN. SIZE	TO INTER-PAN-COAT	TO EL				EDGE	GEN.	EL	TOPCOAT	PRIMER		
126	10-10	E 4-1/2						TR.	CR.			7	10-									100					
127	0											-										-					
142	8	9	4-1/2			9	2 1/4	5	CR.			7										98					
149	10-TRs.	E 4-1/4										7										100					
156	0																					-					
170	8	8	4-1/2									-										50					
84	10-TRs.	4-1/2						8	CR.			-										100					
113	10-TRs.	4-1/2						7	"			-										100					
134	8	8	4-1/2									0										100-					
163	10-10	E 4-1/2										0										100					

Company
Code Number G-6100-2
Date placed on test 9-30-75
Date this inspection 3-17-77

[illegible]

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

DAYTONA BEACH, FLA.

Company

Code Number G 6100-2

Date placed on test 9-30-75

Date this inspection 3-17-77

Legend: 10=Perfect; 0=Complete Failure
S = SEED; P = PINPOINT; E = EDGE; CR = CREEPING;
L = LOOSE; ML = MAINLY LOOSE; LT = LOOSE & TIGHT.
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

FOULING DESCRIPTION										PAINT CONDITION															
RATING: 10 TO 0, 0=COMPLETE FOULING										RATING: 10 TO 0, 0=COMPLETE FAILURE															
PANEL NUMBER	GEN. FORM-ANCE	BARNACLES		MOLLUSKS		ANNELIDS		HYDROIDS		BRYOZOA		FILIP ALGAE	SCUM AND SILT	BLISTERING		PEELING		CORROSION		EDGE-ING	CHALK-ING	CRACK-ING	ALLIGATORING	% AREA COATING INTACT	
		RATING	SIZE	RATING	SIZE	RATING	SIZE	ENCrust-ING	FILAMEN-TOUS	RATING	SIZE			EDGE	GEN. SIZE	TO INTER-COAT	TO PAN-EL	EDGE GEN.	EDGE GEN.					TOPCOAT	PRIMER
123	10							10- CR				7	10-					9							100-
130	0			Mainly barnacles								-								Obscured by fouling					-
145	10- TR.	F 1/2				10- 1/2		7 CR			TR.														100
152	10										6									Obscured by fouling					100
159	0			Mainly barnacles							-									Obscured by fouling					-
173	0					do-					-									- do -					-
87	10																								100
116	10																								100
137	9	ME 1/4-1/2										0						9							98
166	10- 9	F 1/2										0						TR							100-

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Company
Code Number G6100-2
Date placed on test 9-30-75
Date this inspection 3-17-77

Legend: 10=Perfect; 0=Complete Failure
S - SEED; P - PINPOINT; E - Edge; CR - Creeping;
L - LOOSE; ML - MAINLY LOOSE; LT - LOOSE & TIGHT;
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

PANEL NUMBER	FOULING DESCRIPTION RATING: 10 TO 0, 0=COMPLETE FOULING										PAINT CONDITION RATING: 10 TO 0, 0=COMPLETE FAILURE							% AREA COATING INTACT	
	GEN. PER- FORM- ANCE	BARNACLES	MOLLUSKS	ANNELIDS	HYDROIDS	BRYOZOA		SCUM AND SILT	BLISTERING	PEELING	CORROSION	CRACK- ING	CRACK- ING	CRACK- ING	CRACK- ING	CRACK- ING	CRACK- ING	TOPCOAT	PRIMER
43	10- TR.	E 1/4		TR. 2"	6 CR.			TR. 10-	10-	10-	8	10-						98	
36	10				6"			10-	9	8	8	10-						92	
57	10				6"			10-	9	10-	8							96	
63	10				6"			10-	9	10-	10-							100-	
78	10- 10-	E 1/4- 1/2			6"			10-	TR. 9	TR. 10-	10- TR.							99	100-
71	10- 10-	E 1/4- 1/2			6"			10-	TR. 9	TR. 10-	9	10-						94	
50	10				9"			10-	4	4	10- TR.							40	
92	10- 10-	E 1/4- 1/2			9"			10-	TR. 10-	TR. 10-	10- 10-							96	
99	0							10-			Observed by footing							—	
106	0							10-			Observed by footing							—	

Recorded

Florida Marine Research Laboratories
BATTELLE MEMORIAL INSTITUTE
DAYTONA BEACH, FLA.

17 Pages; Page 14

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Company
Code Number G-6100-2
Date placed on test 9-30-75
Date this inspection 3-17-77

Legend: 10=Perfect; 0=Complete Failure
S - SEED; P - PINPOINT; E - EDGE; CR - CRACKING;
L - LOOSE; ML - MAINLY LOOSE; LT - LOOSE & TIGHT;
RATING OF 10 OMITTED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

		FOULING DESCRIPTION										PAINT CONDITION														
		RATING: 10 TO 0, 0=COMPLETE FOULING										RATING: 10 TO 0, 0=COMPLETE FAILURE														
PANEL NUMBER	GEN. PER- FORM- ANCE	BARNACLES		MOLLUSKS		ANNELIDS		HYDROIDS		BRYOZOA		ALGAE	FILM	SCUM AND SILT	BLISTERING		PEELING		CORROSION		EROD- ING	CHAL- ING	CRACK- ING	ALLIG- ATORING	% AREA COATING INTACT	
		RATING	SIZE	RATING	SIZE	RATING	SIZE	ENCrust- ING	FILAMEN- TOUS	RATING	SIZE				EDGE	GEN.	SIZE	TO INTER- COAT	TO PAN- EL	EDGE					GEN.	TOPCOAT
121	10							TR, CR				TR	10-				TR									100-100
128	0			Mainly barnacles.								-								Obscured by failings						-
143	7	ME 1/2				7	2 1/2	8	CR								9									98
150	10-TR							TR				10-														100
157	0			Mainly barnacles																Obscured by failings						-
171	5	5	4-5			9	2	Fouled where coating peeled -									3			Running coating all over area						30
85	10																									100
114	10																									100
135	10-10	ME 4-5																								99
164	10-TR	ME 4-5																								100-

INSPECTION REPORT — MARINE IMMERSION EXPOSURE

Legend: 10--Perfect; O=Complete Failure
S = SEED; P = PINPOINT; E = EDGE; CR = CREEPING;
L = LOOSE; ML = MAINLY LOOSE; LT = LOOSE & TIGHT.
RATING OF 10 UNITED UNLESS A RATING OTHER THAN
10 EXISTED AT PREVIOUS INSPECTION.
DASH (—) INDICATES THAT RATING CANNOT BE DETER-
MINED DUE TO SOME OTHER CONDITION.

Company
Code Number *G6100-2*
Date placed on test *10-8-70 (016 Series)*
Date this inspection *3-18-77*

[illegible]

8. APPENDIX C

PHOTOGRAPHS OF COATING SYSTEMS
AFTER 18 AND 77 MONTHS' IMMERSION



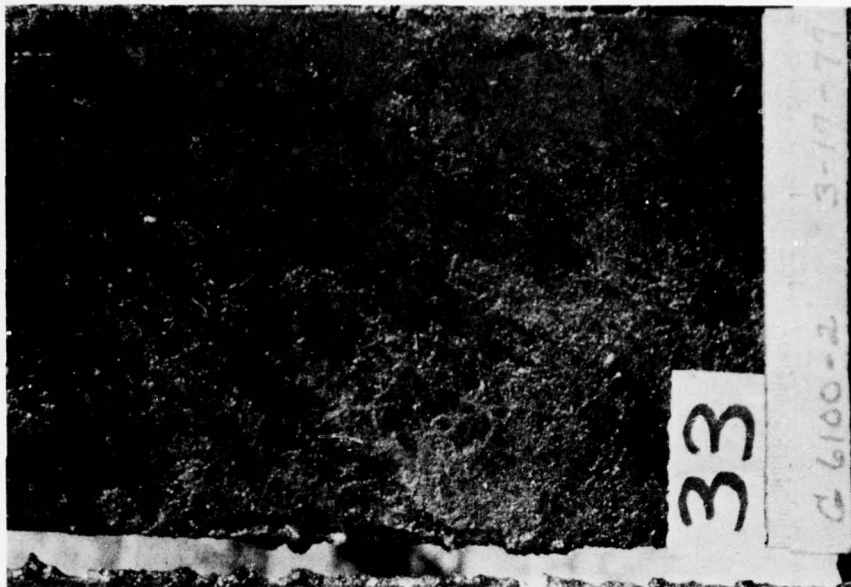
Panel No. 40
System No. CG-19
Type 121/63 Vinyl High
Rosin Control on Steel

18 Months' Exposure



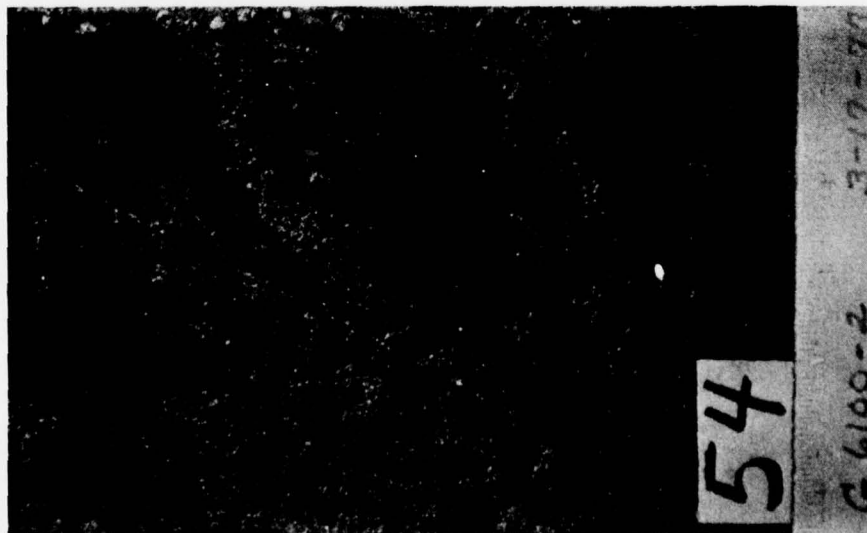
Panel No. 82
System No. CG-20
Elastomeric Sheet With Organotin
Toxicant on Steel

18 Months' Exposure



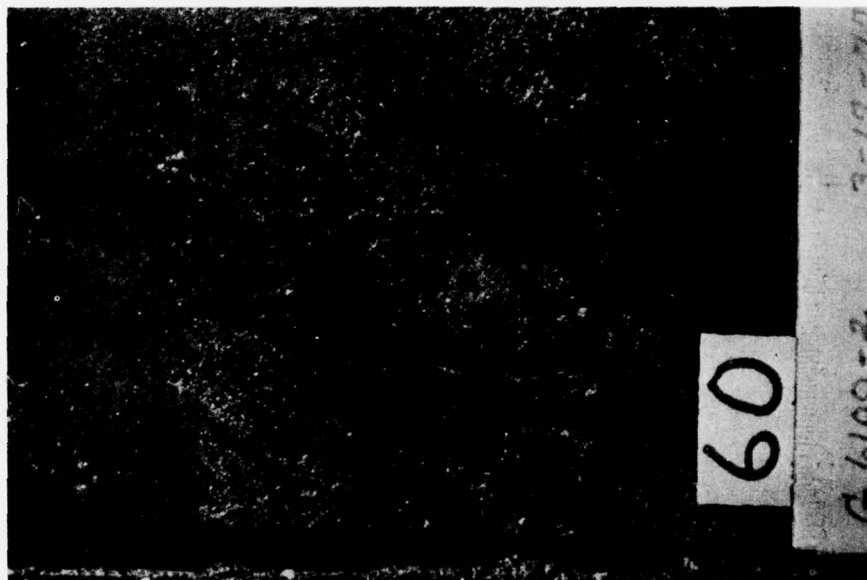
Panel No. 33
System No. CG-21
Type 121 Standard Vinyl
Rosin Control on Steel

18 Months' Exposure



Panel No. 54
System No. CG-22
Self-Cure Zinc Standard
Vinyl Rosin Control on Steel

18 Months' Exposure



Panel No. 60
System No. CG-23
Postcure Zinc Standard Vinyl
Rosin Control on Steel

18 Months' Exposure



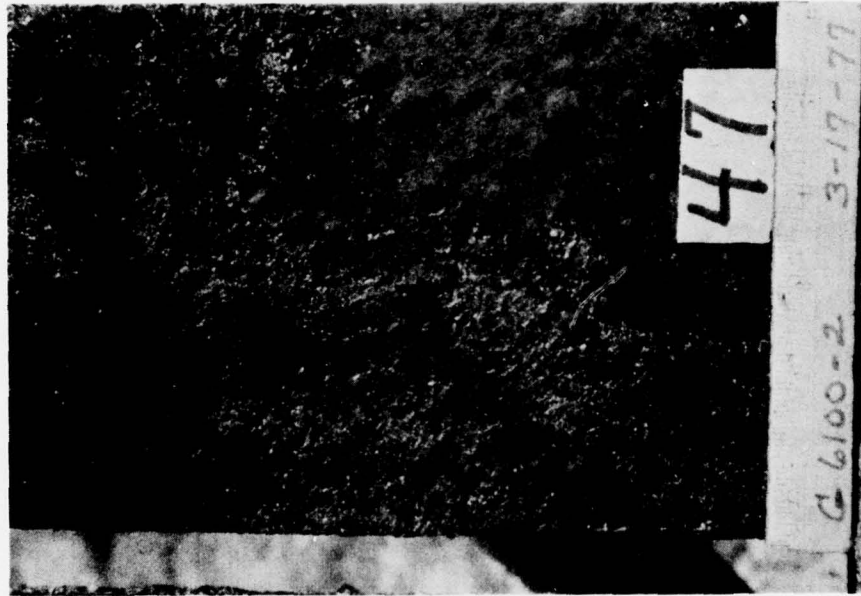
Panel No. 75
System No. CG-24
Epoxy Primer Standard Vinyl
Rosin Control on Steel

18 Months' Exposure



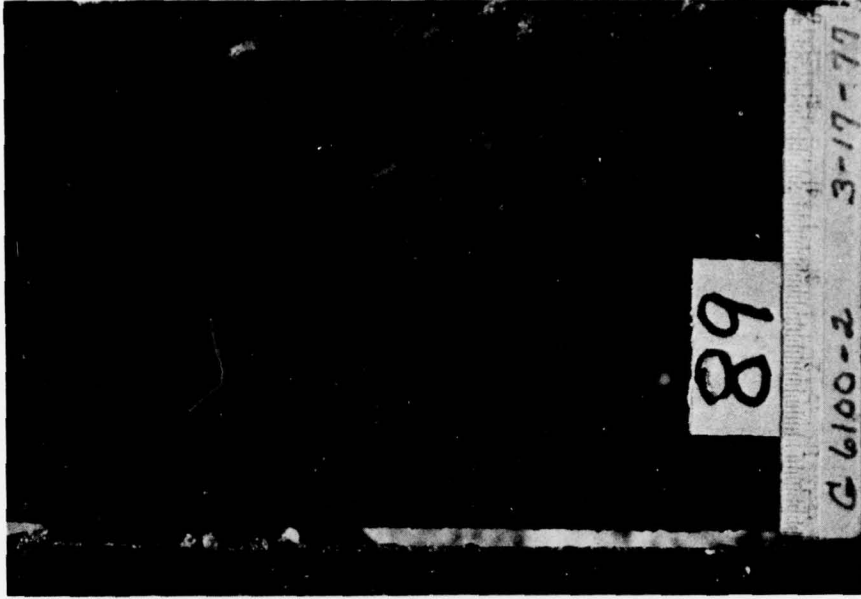
Panel No. 68
System No. CG-25
Type 121 Applied Quickly (Before
Complete Cure) Over Epoxy Primer and
Anticorrosive on Steel

18 Months' Exposure



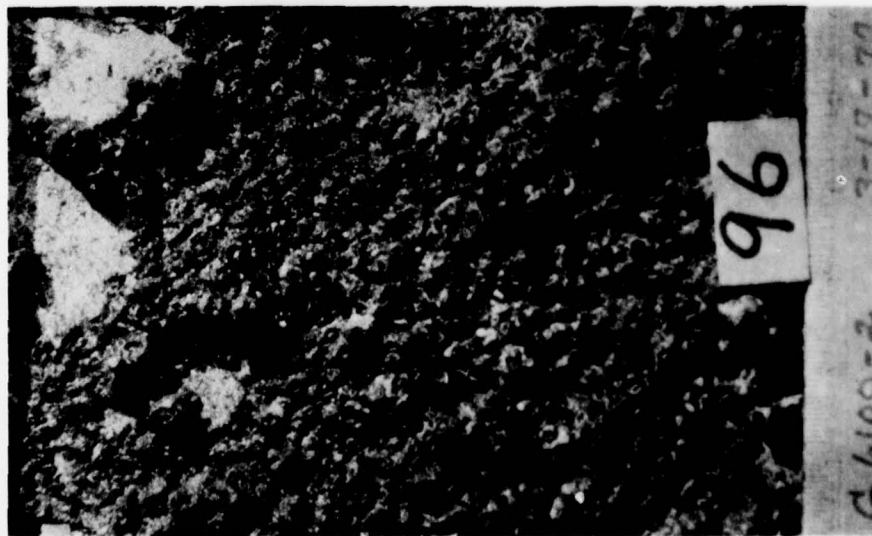
Panel No. 47
System No. CG-26
Type 121 Applied Over Sanded
Polyester Glass Flake
Anticorrosive on Steel

18 Months' Exposure



Panel No. 89
System No. CG-27
Resin-Chlorinated Rubber with TBTF
Toxicant Over Coal Tar-Epoxy
Anticorrosive on Steel

18 Months' Exposure



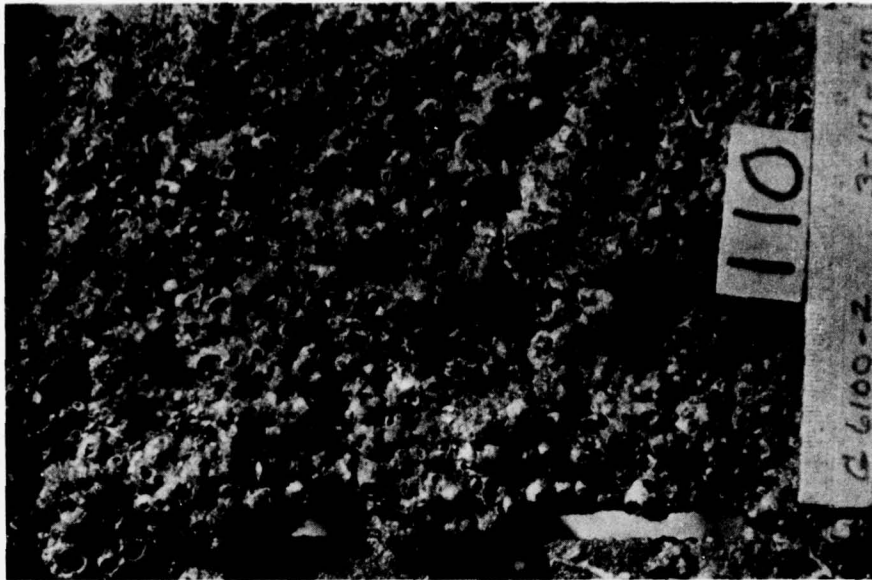
Panel No. 96
System No. CG-28
Flame Sprayed Copper
Cladding over Polyester
Glass Flake on Steel

18 Months' Exposure



Panel No. 103
System No. CG-29
Acrylic-Organometallic Toxic
Polymer Over Type 119
Anticorrosive on Steel

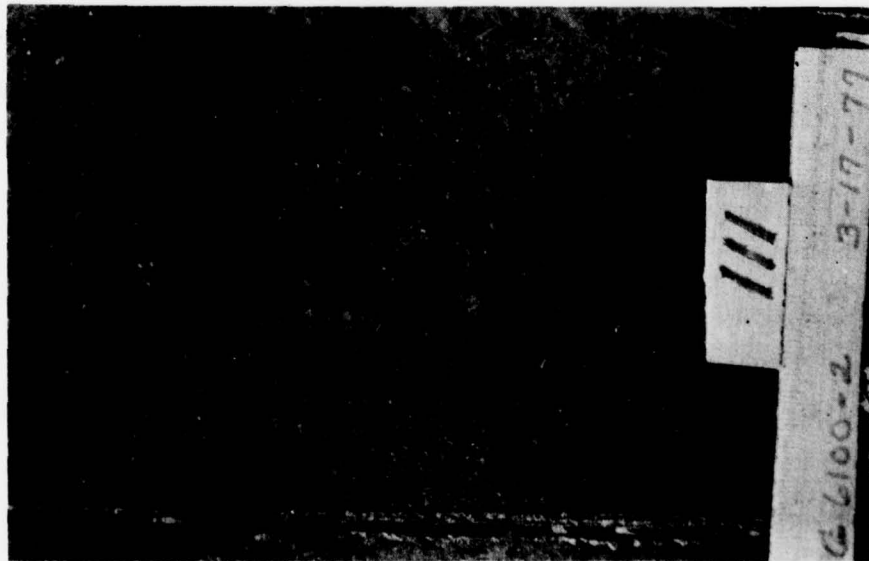
18 Months' Exposure



Panel No. 110

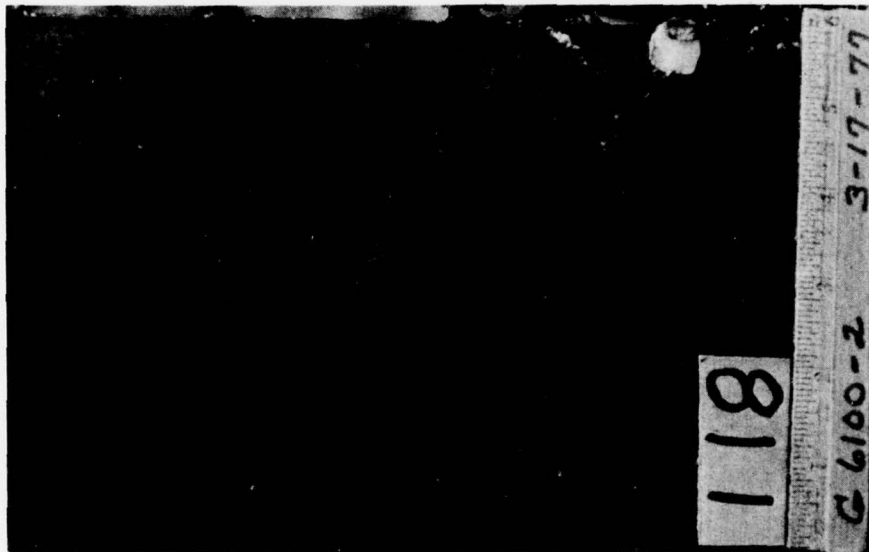
Uncoated Steel Control Panel

18 Months' Exposure



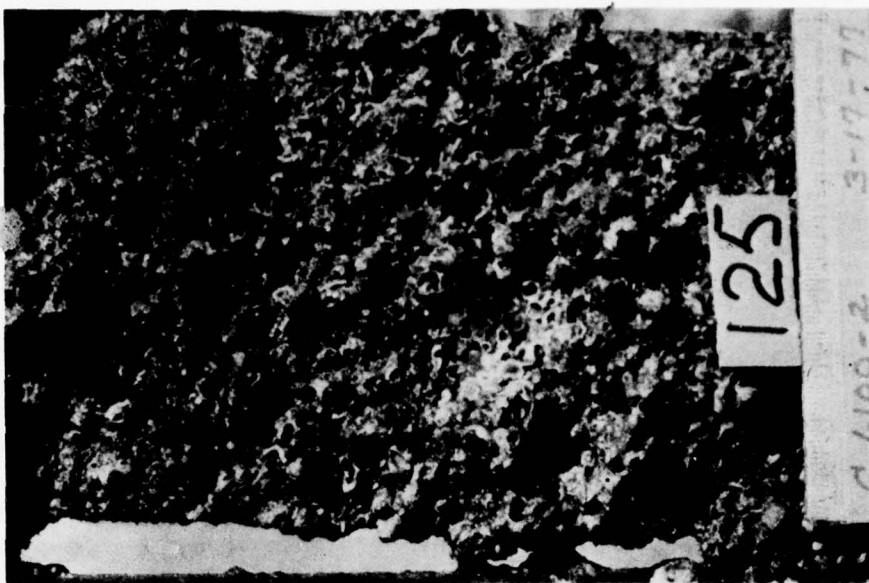
Panel No. 111
System No. CG-30
Elastomeric Sheet With Organotin
Toxicant on Aluminum

18 Months' Exposure



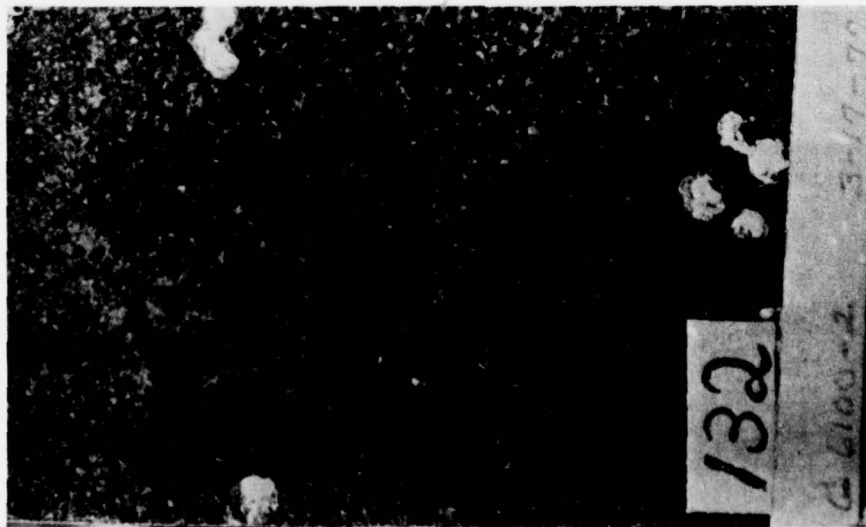
Panel No. 118
System No. CG-31
Rosin-Chlorinated Rubber
Antifoul With TBTF
Toxicant on Aluminum

18 Months' Exposure



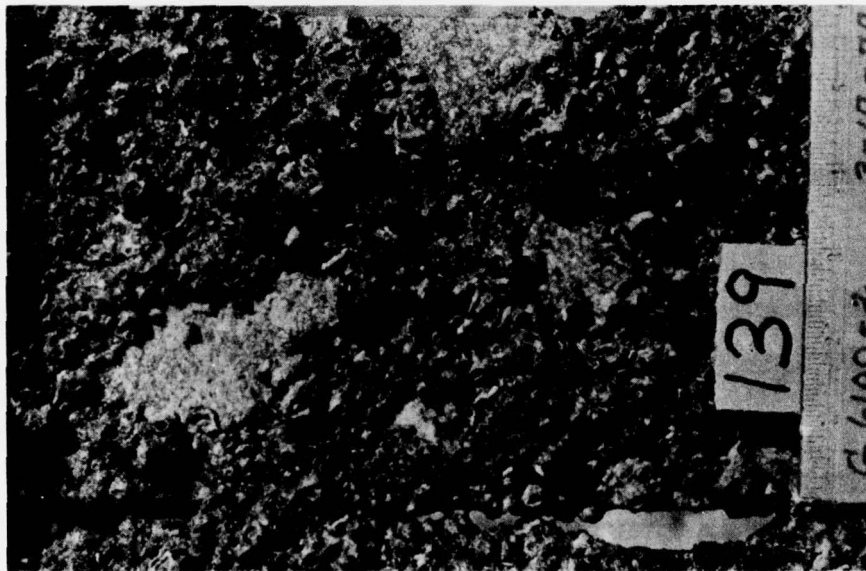
Panel No. 125
System No. CG-32
Acrylic-Organometallic Toxic
Polymer on Aluminum

18 Months' Exposure



Panel No. 132
System No. CG-33
Rosin-Chlorinated Rubber
Antifoul With TPTF Toxi-
cant on Aluminum

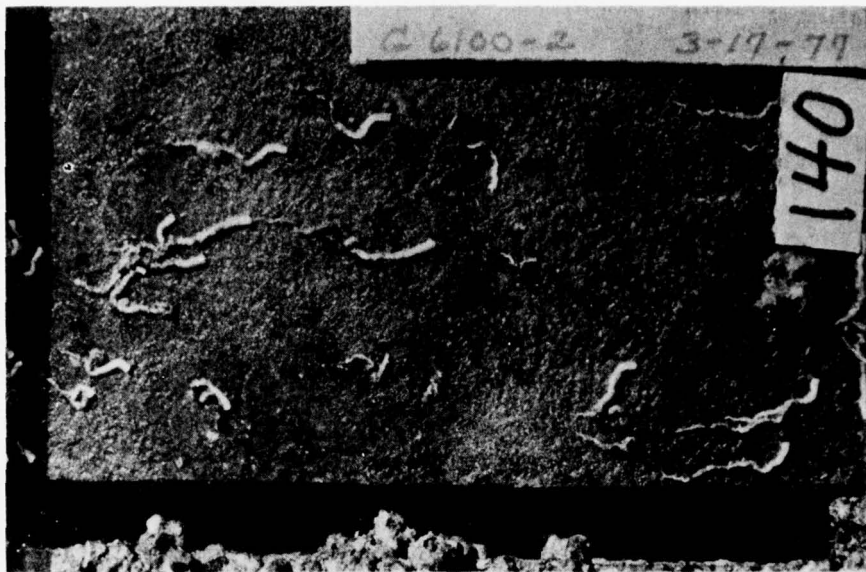
18 Months' Exposure



Panel No. 139

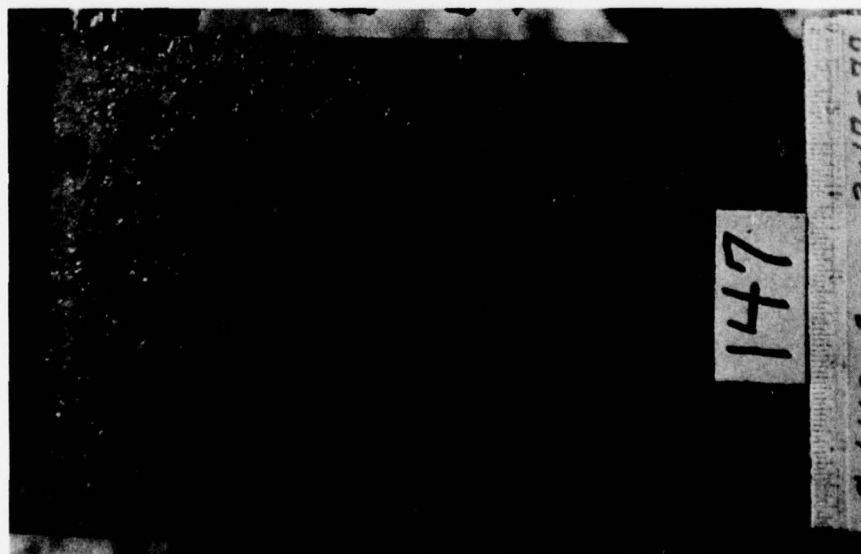
Uncoated Aluminum Control Panel

18 Months' Exposure



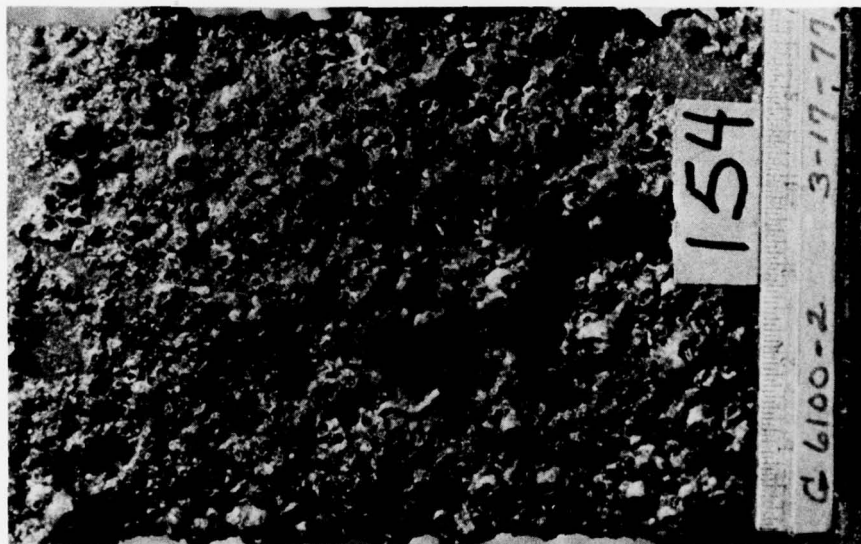
Panel No. 140
System No. CG-34
Type 121/63 Vinyl-High
Rosin Control on Plastic

18 Months' Exposure



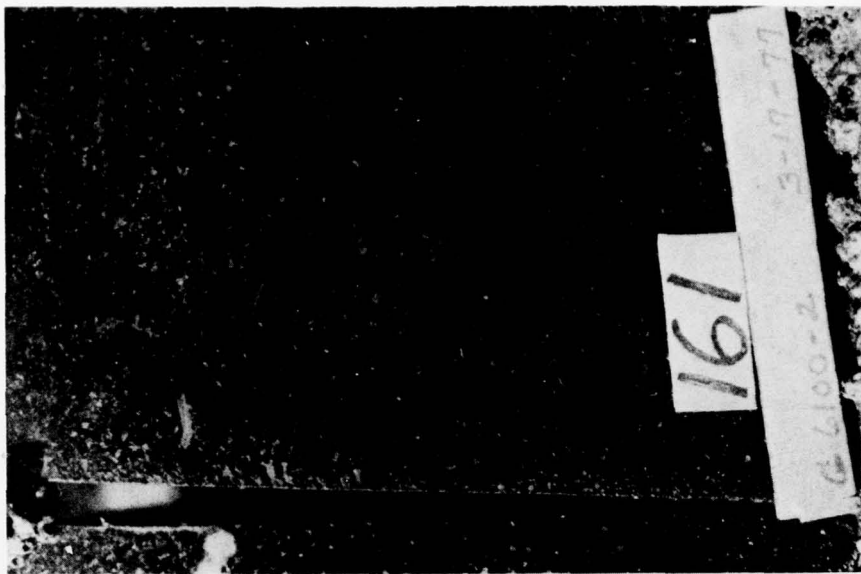
Panel No. 147
System No. CG-35
Rosin-Chlorinated Rubber Antifoul
With TBTF Toxicant on Plastic

18 Months' Exposure



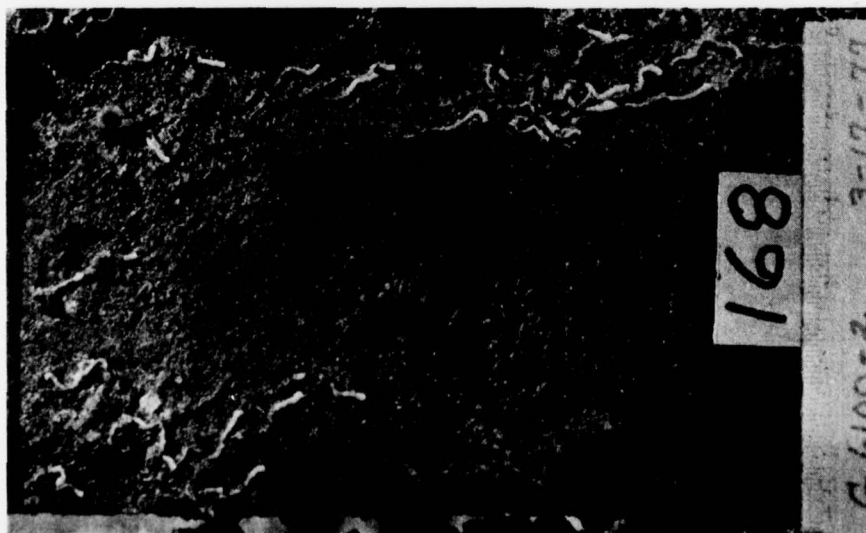
Panel No. 154
System No. CG-36
Acrylic-Organometallic Toxic
Polymer on Plastic

18 Months' Exposure

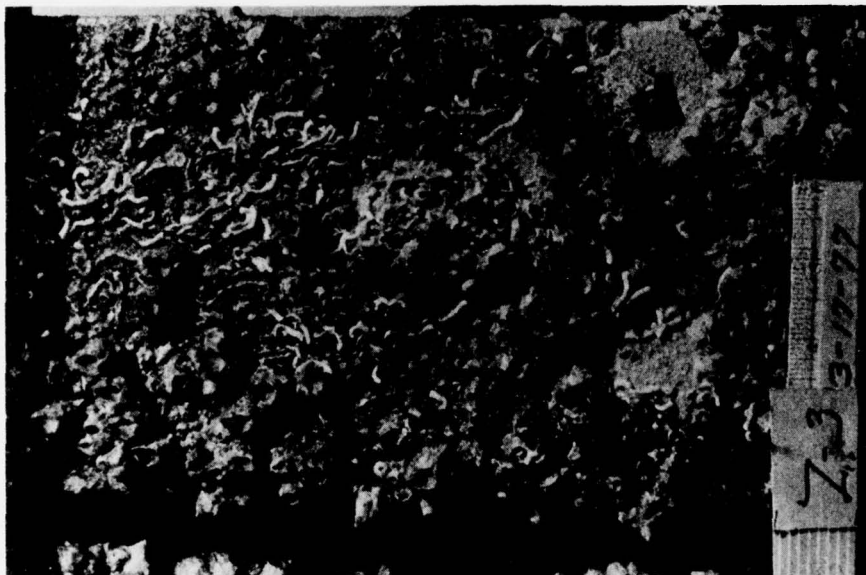


Panel No. 161
System No. CG-37
Rosin-Chlorinated Rubber Antifoul
with TPTF Toxicant on Plastic

18 Months' Exposure



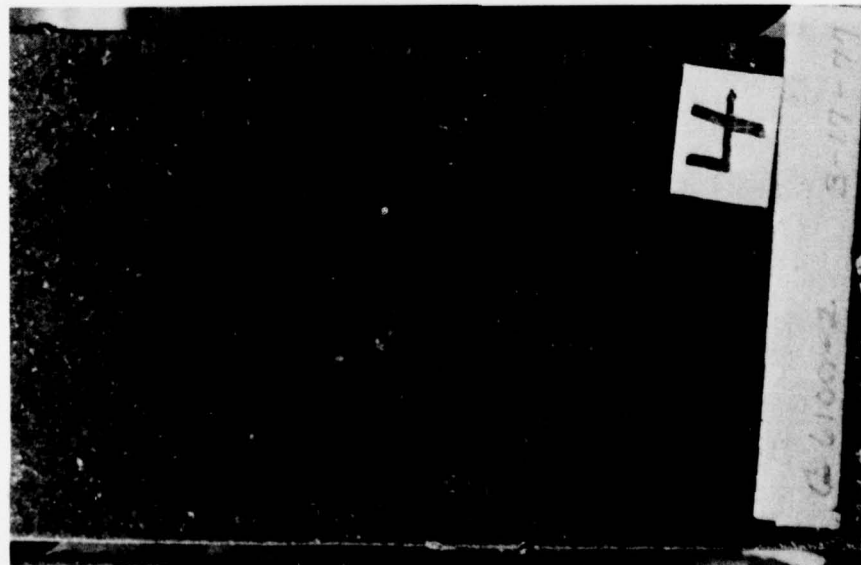
Panel No. 168
System No. CG-38
Flame-Sprayed Copper
Cladding on Plastic
18 Months' Exposure



Panel No. Z3
System No. CG-40
Nonsolvent Polyurethane
on Steel
18 Months' Exposure

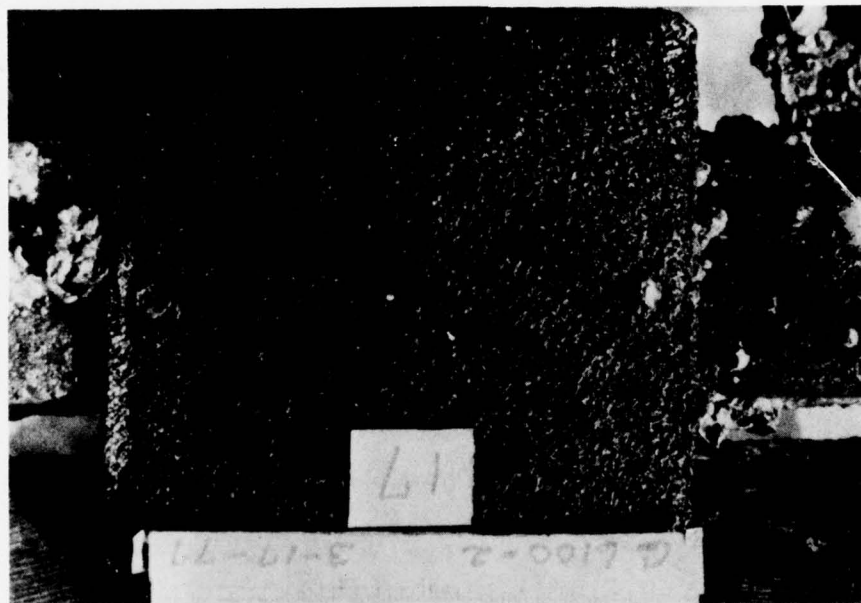


Panel No. Z5
System No. CG-41
Nonsolvent Polyurethane
on Aluminum
18 Months' Exposure



Panel No. 4
System No. CG-2
Type 121/63 Vinyl-High
Rosin Control

77 Months' Exposure



Panel No. 17
System No. CG-17
Elastomeric Sheet With
Organotin Toxicant

77 Months' Exposure



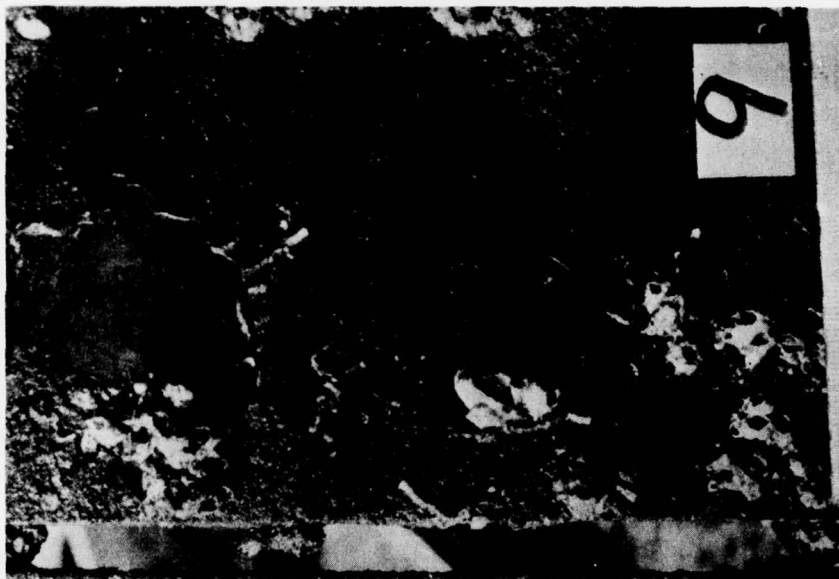
Panel No. 1
System No. CG-1
Type 121 Standard Vinyl-
Rosin Control

77 Months' Exposure



Panel No. 8
System No. CG-4
Self-Cure Zinc Silicate High-Build
Vinyl, Type 121 Antifoul

77 Months' Exposure



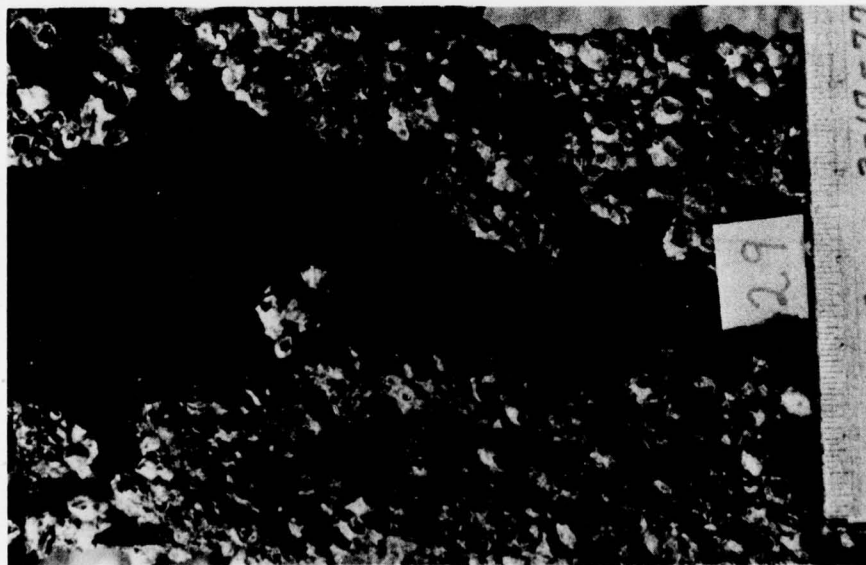
Panel No. 9
System No. CG-1
Postcure Zinc Silicate, High-Build
Vinyl, Type 121 Antifoul

77 Months' Exposure



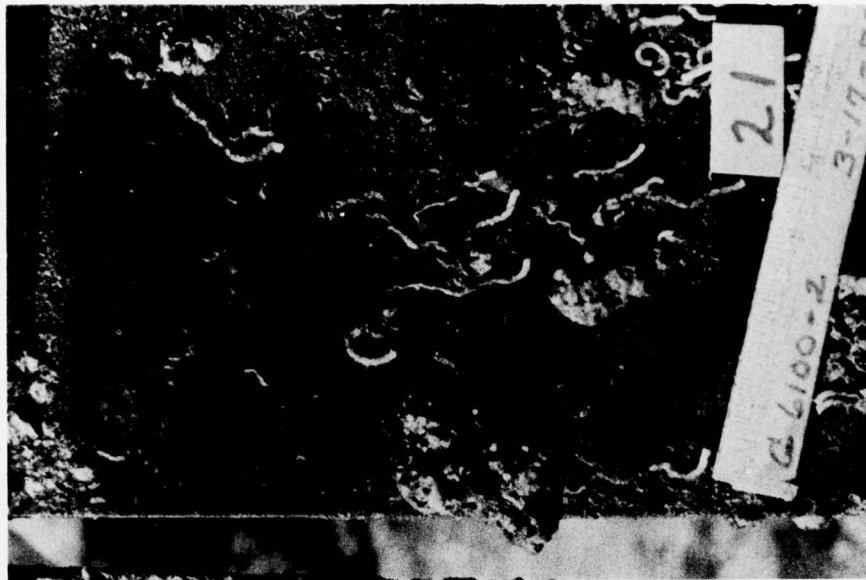
Panel No. 28
System No. CG-14
Vinyl-Rosin with Organotin (TBTF)
Toxicant, Aluminum Substrate

77 Months' Exposure



Panel No. 29
System No. CG-15
Vinyl-Rosin With Organotin (TBTF)
Toxicant, Fibreglass Substrate

77 Months' Exposure



Panel No. 21
System No. CG-11
Epoxy Primer, Epoxy-Coal
Tar Anticorrosive and Antifoul

77 Months' Exposure